DORSEY & WILSON

Electric Lighting of Class Rooms

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ELECTRIC LIGHTING OF CLASS ROOMS

BY

OTIS BOND DORSEY
AND
FRANK HARLAND WILSON

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

OTIS BOND DORSEY AND FRANK HARLAND WILSON

ENTITLED ELECTRIC LIGHTING OF CLASS ROOMS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

H. F. Hake
Instructor in Charge

APPROVED: Ernst Berg

HEAD OF DEPARTMENT OF ELECTRICAL ENGINEERING.

C O N T E N T S .

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ELECTRIC LIGHTING OF CLASS ROOMS.

The problem of satisfactory lighting of class rooms and small lecture rooms in public school and college buildings has long been a difficult one. A great majority of the lighting systems installed in such rooms previous to only the last few years are now considered very poor from the standpoints of both effectiveness and efficiency. Even in university buildings constructed as recently as 1907 or 1908 and up-to-date in all respects at that time, the lighting methods are today considered so poorly adapted as to be entirely out of the question at the present time.

In the last few years, great advances have been made in a comparatively new branch of engineering--"illuminating engineering"--to which the discovery of the metallic filament incandescent lamp gave a great impulse. A large amount of time and money have been spent in scientific research the object of which is the betterment of both illumination methods and the illuminants themselves. Indeed, the large manufacturers of electric lighting equipment have cooperated in permanently maintaining a corps of special investigators whose duties are to test out new ideas which may result in improvements, and to answer all inquiries requesting recommendations as to the proper method of lighting to be used in particular cases. Thus, today the contractor is not handicapped, as was formerly the case, by lack of proper equipment or of knowledge concerning the correct way to use such equipment. He is no longer obliged to use the same

fixtures, perhaps in a somewhat modified form. for class room and grocery store. The variety of methods, fixtures, lamps, reflectors and accessories is now so large that it is possible to select for any particular room such a system of lighting that will furnish effective, and at the same time economical illumination-- and this not at the expense of artistic appearance that may be desirable.

In designing a lighting installation for a class room or lecture room, the following conditions should be complied with:

(a) There should be enough illumination that the eyes need not be strained in reading, in looking at the lecturer, or at the blackboard. To ensure this, it is necessary to get the proper amount of light upon the plane of the desk tops or chair arms, and also upon a plane at the height of the blackboard.

(b) There should not be too much illumination. If the light is too strong it will tire the eyes. Many hold the fallacious idea that the more brilliantly lighted a room is, the better is the illumination. As a matter of fact, too strong a light is fully as harmful to the eyes as is one that is too weak. The proper intensities of illumination for various uses will be found in Table 1 in the Appendix.

(c) There should be no extremely bright lights directly in the line of vision of any person in the room. This fault is almost without exception found in the older installations. The result is that the eyes are dazzled and the observer must strain to see. Dazzling effects are often caused by the use of lamps of high intrinsic brilliancy with improper reflectors. Other causes

are the hanging of the lamps too low, and the use of unfrosted lamps. When reflectors are used, the lamps should have the bottom portion, or bowl, frosted. Such frosting softens and diffuses the brilliant light.

(d) The light should be evenly diffused and distributed throughout the room. The persons near the walls should receive as good illumination as those in the center of the room. Many class rooms, although using a sufficient wattage of lamps, have excessive illumination in a small zone under the lamps, and weak illumination only a few feet distant.

(e) The color of the light should be as near daylight as possible. The light of the tungsten lamp approximates daylight very closely. Green lights, such as that given by the mercury vapor lamp, and blue lights, such as the carbon arc gives, should not be considered as possible means of class room illumination, since they are too "cold" and unpleasant, to say nothing of other disadvantages.

(f) The light should be steady. A flickering light, like that of an arc lamp or incandescent lamps on circuits of fluctuating voltage, is hard on the eyes and tends to distract the attention.

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The writers have investigated three methods of lighting a class room by means of incandescent lamps. The class room upon which the investigation is based is a small lecture room in the Electrical Laboratory building of the University of Illinois. The plan of the

room is shown on page 33. In the first two methods direct lighting is used, and in the other, indirect lighting. The several systems will be referred to in the remainder of this paper as

I.-- Direct System "A".

II.-- Direct System "B"

III.-- Indirect System.

I.--DIRECT SYSTEM "A".

The first method of lighting the small lecture room is one that involves the use of several fixtures equipped with tungsten lamps and Holophane prismatic glass reflectors. This system is in very common use at the present time.

In designing a system of this kind the number of outlets should first be decided upon. In general the number of outlets should be kept as low as is consistent, in order to keep down the cost of wiring and fixtures. In a room as narrow as the small lecture room that has been taken for the purpose of illustration, but one row of fixtures would be required lengthwise of the room. However, on account of the extreme length of the room, more than one fixture would be required, if uniform illumination is desired. The usual method of determining the number of outlets is to divide the ceiling into squares and place an outlet in the center of each square. Using this method for the room under discussion, it is found that three outlets are required, one being located in the center of the room and the others a distance from it equal to one-third the length of the room.

The number of lamps per fixture depends upon whether or not artistic appearance is desired. As far as the quality and amount of illumination is concerned, that furnished by a single large lamp is equal to that given by a group of small units, the total lumens per fixture being the same. However, the appearance of a fixture depends largely upon how many units it carries, within limits. A single-unit fixture would look "skimpy" and unattractive in a lecture room, although it would undoubtedly provide the proper illumination. A four-light fixture, however, is well-balanced, has an attractive appearance, and is not too expensive.

The intensities of illumination required for various uses are, as previously stated, given in Table 1 in the Appendix. This table is based on the recommendations of the National Electric Lamp Association. The proper intensity for a class room is seen to be 2 to 3 foot-candles. This illumination should be obtained upon a plane 30" above the floor, 30" being the usual height of desk tops and chair arms.

The type of reflector that should be used depends upon the area to be lighted by one fixture. If the area is large, extensive reflectors should be used; if small, intensive reflectors. In the room under consideration a fairly large space must be taken care of by each fixture; the extensive type, the distribution curve of which will be found on page 32, should therefore be chosen. Having settled upon the proper type of reflector, and knowing the height of the plane of reference (i.e., 30" in the case of a class room) the proper mounting height of the lamps may be determined for any

distance between outlets by the use of the curves on page 31. These curves were prepared by the Holophane Company, and apply only to Holophane glass reflectors.

Knowing the number of lamps, the required intensity, and the total area to be lighted, the size of lamps necessary to furnish the desired intensity may be calculated by means of the following formula, which is recommended by the National Electric Lamp Association:

$$\text{No. of lamps} = \frac{\text{Area in sq. ft. x required foot-candles}}{\text{Effective lumens per lamp}} \quad \ldots(1)$$

By solving this equation the number of "effective lumens per lamp" is found. Then from Table 2, Appendix, the number of watts per lamp corresponding to this value of effective lumens is determined, the nearest standard size being taken.

We are now ready to calculate the illumination at any point in the 30" plane. A plan of the room drawn to scale and showing the positions of the outlets must first be prepared. On page 20 is the plan of the the small lecture room. In calculating the intensity at any point A (see page 20), the following process is carried out: The distance from A to each of the lamps is measured. The corresponding intensity at A due to each individual lamp is then read from a "foot-candle curve" for the particular reflector, lamp, and distance of the reference plane below the lamp. Such a curve is plotted with "horizontal distance from a point directly beneath the lamp" as abscissae, and "foot-candles of illumination at the point" as ordinates. Illumination calculated in this way must be increased by a certain percentage of the calculated value according to the

color of the walls and ceiling. Table 3, appendix, gives the percentages of increase over calculated illumination that should be allowed with various colors of walls and ceilings. Almost no light is reflected from dark-colored spaces, such as blackboards, dark wainscoting, and windows having green shades. Such spaces should be taken into consideration in estimating the proper percentage of increase for a particular room.

If the illumination be calculated as above suggested for various points in the 30" plane, and the results tabulated, lines may be plotted, on a map of the floor area, connecting all points of equal illumination. These lines, when plotted for illuminations of of 75%, 100%, 125%, etc., give a set of curves which are analoguous to isothermal lines, isogonic lines etc., forwhich reason the name "isolux" curves has been given to them. For a class room these curves may be plotted for three planes-- 30", 3', and 5'. Thirty inches is, as previously stated, the usual height of desk tops and chair arms. The 3' plane should be taken since this is the height at which a book would be held in reading. The 5' plane might also be included for the purpose of determining what illumination is obtained on the blackboard. By means of the isolux curves the uniformity of the illumination may be determined, as will be explained later.

Using the above suggestions, the calculations for the lighting of the small lecture room by means of Direct System "A" have been made, as follows:

Dimensions of room (see plan, page 33) . . . . 23'x51'

Ceiling height . . . . 12'6"

Ceiling color . . . . Lt.Cream.

Dark spaces on walls . . . . Continuous 4' blackboard on one side and one end; dark wainscoting extending entirely around room, height 3'; 5 triple windows with dark green shades on side opposite blackboard.

No. of outlets 3

Lamps per outlet 4

Total No. of lamps 12

Required foot-candles 2.5

Effective lumens per lamp (formula (1)) 245

" " " " ,nearest standard size 250

Lamp corresponding to 250 eff. lumens(Table 2), . . .

. . . . . 60-watt tungsten.

Distance between outlets = 51'/3 = ... 17'

Height of reference plane above floor . . . . . . 30"

Mounting height of lamps (curve,page 31). . . . . 10'6"

Proper reflector. . . . . Extensive Holophane, No.E60.

Sample calculation of illumination . . . . Point A, on plan of room, page 20, position 18' east of west wall and midway between the long sides. Arms of fixture assumed to be each 1' long. -- Measured distances from each lamp to the point: 0.5',1.5', 2.5', 14.5', 15.5', 16.5', 16.5', 17.5', 18.5'. Foot-candles corresponding to each point, from foot-candle curve, on

page 29: 0.66, 0.66, 0.06, 0.07, 0.06, 0.045, 0.045, 0.04, 0.035 . Total foot-candles, 2.28 . This value will have to be increased by a certain percentage. Table 3 advises 80% increase over calculated illumination when both walls and ceiling are very light. The room under consideration has very light walls and ceiling, but on one side most of the wall was taken up by windows having dark shades, and the other side had a continuous blackboard, beneath which was a dark wainscoting. The remaining end wall was unobstructed by dark spaces save for the low wainscoting. Practically no light, therefore, was reflected from about one-half of the walls, so the proper percentage of increase is about 40%. This will bring the calculated illumination of 2.28 foot-candles up to 3.20 .

II. - - D I R E C T S Y S T E M " B " .

In the second system of direct lighting, the same number of lamps is used as in Direct System "A", but each lamp is hung on a separate fixture. From formula (1) the size of lamp required to provide the same intensity of 2.5 foot-candles is found to be the same as in system "A", i.e., 60-watt.

Since there is to be one lamp per fixture the number of outlets is 12. Each outlet should be placed, in accordance with the usual rule, in the center of a square, as mentioned in the discussion of system "A". The outlets will, then, be located in two rows lengthwise of the room, each row containing six outlets. With this arrangement, the distance between outlets the long way of the room

will be one-sixth of 51', or 8'6", placing the end outlets 4'3" from the end walls. The spacing distance crosswise of the room will be one-half of 23', or 11'6"--say 12'. Each outlet will then be 5'6" from the adjacent wall.

The mounting height of the lamps may now be found from the curves on page 31. The spacing distance in this case should be taken as the mean of the lengthwise and crosswise spacing distances, or 10'3" . An inspection of the curves shows that if extensive reflectors are used the lamps must be mounted 7'6" above the floor. This is entirely too low for a long room, as the light would be directly in the field of vision. With focusing reflectors, the mounting height would have to be 17'-- higher than the ceiling. With intensive reflectors, however, the mounting height would be 10'6", or 2' from the ceiling, which is satisfactory. Hence, Holophane glass reflector No. I 60 is the proper one to use. The distribution curves of the three types of reflectors will be found on pages32,33,and 34.

The illumination at any point may now be calculated and data obtained for plotting the isolux curves. The curves obtained by the writers for this system will be found on pages 21,24, and 27.

III.--I N D I R E C T   S Y S T E M.

In the indirect system of illumination the light from concealed lamps is thrown upon the ceiling, from which it is diffusely reflected downward onto the plane of reference.

In planning an indirect lighting installation, the first thing to be considered is whether or not the room is suited to such a system of illumination. " The first requisite is a light-colored ceiling. Pure white is the best reflector, and the nearer white the color of a ceiling the more efficient will be the reflection from it. It is usually desired to introduce some tint which will be more pleasing than dead white for decorative reasons. The addition of any tint lowers the efficiency, but a cream tint, for example, lowers the efficiency less than does green, which is a very inefficient reflector; in fact, considerable cream tint can be introduced without seriously affecting the efficiency of reflection. Brown and red are, of course, very inefficient. The color which is likely to be most deceptive is gray. Even the lighter tints of gray are poor reflectors, as they contain much black, gray being really a mixture of black and white."[1]

With the question of color of ceiling disposed of, the type of indirect system may be decided upon. The two common types are (1) the cove system, in which the light comes from a large number of small lamps concealed in troughs or coves which throw the light up onto the ceiling; and (2) the fixture system, in which high-candle-power lamps provided with inverted reflectors are supported on pendant fixtures the outlets for which are, in general, located the same as for direct lighting. Cove lighting requires special shapes of ceilings to obtain reasonable efficiencies, hence its use is restricted. With the fixture system, however, the best efficiency is obtained with the ordinary flat ceiling.

Figure 1 shows an indirect unit hung in the center of a room with a flat ceiling. The reflector throws a cone of light to the ceiling. Most of the light strikes the ceiling within the base BC of the cone and is reflected downward therefrom by the myriad of particles of which the ceiling is composed. Although any ordinary ceiling is a diffuse, and not a regular, reflector, it may be considered so because more reflection takes place at the regular angle than at any other. Referring again to figure 1, let AB and AC be the rays bounding the cone of useful light. The regularly reflected rays are then CE and BD. If these rays strike the wall at the height of the plane of reference, the whole of the latter will be covered, and the lamp is therefore hanging at the proper height. The effect of raising the unit is to cause the reflected rays to strike the wall below the reference plane, and only a part of the latter is covered. If the unit be lowered, the rays CE and BD will strike the walls above the reference plane, causing them to be reflected twice before reaching the plane of reference. This would cause a considerable loss.

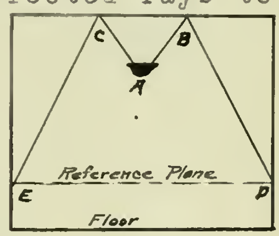

Fig. 1.

In determining for any room the proper mounting height of the lamps, the following method is recommended by J.R.Cravath:[1] Prepare for each reflector used a piece of tracing cloth or transparent celluloid having the angle ACE (see figure 1) marked upon it. By laying the angle ACE marked on tracing cloth over the cross-section of the room, the amount of area that can be covered and the mounting height can be found at once.

It is difficult to control the flux of light with indirect lighting because of the diffuse reflection from ceiling and walls. In small high rooms the best results will be obtained by using a concentrating reflector having a distribution curve like Figure 2. For low, wide rooms it is best to use an extensive or distributing reflector with a distribution curve like figure 3.

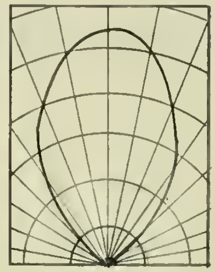

Fig. 2.

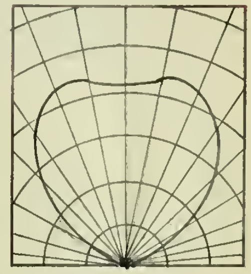

Fig. 3.

In determining the number of lumens to be furnished by the lamps to compensate for losses in reflection, the following formula may be used:

$$\text{Lumens} = \frac{\text{Required foot-candles} \times \text{Area in sq.ft.}}{\text{Efficiency of reflection in \%}} \quad . \; . \; . \; . \; (2)$$

The efficiency of reflection with light walls and ceiling and clean glassware has been found to vary from 30% to 40% under average conditions. Dust and dirt on reflectors will cut down these figures about one-fourth.

Indirect lighting fixtures may be had in almost the same variety as those for direct lighting. Three styles that are very commonly used are shown in the cuts on page 35. Figure 4 is a single-unit fixture using one high-candle-power tungsten lamp. This fixture is intended for lighting moderate-sized spaces. Figure 5 is a fixture of the same type, but intended for lighting large interiors, such as ball-rooms, churches, and hotel lobbies. Instead of a single unit the large bowl contains several lamps. Figure 6 is a four-light fixture, each arm of which carries one medium-candle-power lamp with mirror reflector. It is adapted for lighting moderately

large spaces, the same as Figure 4, the latter being used where a more artistic appearance is desired. Its efficiency is also somewhat better than that of Figure 5, for the same wattage per fixture, this being due to the superior watt-efficiency of the large single lamp.

The above discussion covers the more important points to be considered in designing an indirect lighting installation for any class room of ordinary size or small lecture room. In the small lecture room taken for the purpose of illustration, the indirect fixture system is now installed. Three single-unit fixtures similar to figure 4 are used, each having a 400-watt tungsten lamp with distributing reflector. One unit is hung in the center of the room and the others 17' from it. A separate switch is provided for each.

Using the methods described above, calculations may be made to show how the installation was designed, as follows: --

The proper mounting height of the lamps was found by drawing the cross-section of the room to scale (see Figure 7) and using Cravath's method. The distributing or extensive type of reflector

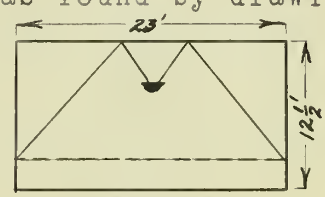

Fig. 7.

was chosen because, as Figure 7 shows, the room is low in comparison with its width. The isolux curves have been plotted from data obtained experimentally by the writers, and will be found on pages 22, 25, and 28. The efficiency of reflection, taking into consideration blackboard, windows, wainscoting, etc., and dirt on reflectors, is estimated as 30%. The data for this indirect installation is tabulated below:

Efficiency of reflection to 30" plane 30%

Required foot-candles 2.5

Area of room, sq.ft. . . . . 1173.

Lumens necessary (formula(2)) . . . . 9770.

Number of outlets 3

Lumens per outlet (i.e.,per lamp) . . . . 3257.

" " lamp, nearest standard size. . . . . 3512.

Watts " " , " " " . . . . . 400.

Location of outlets: Same as for Direct System "A" .

Mounting height of lamps. . . . . 8'6"

Type of reflector . . . . .Distributing.

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C O M P A R I S O N   O F   M E T H O D S .

The uniformity of the illumination may, as previously stated, be determined for a given plane of reference by means of the isolux curves for that plane, as follows: -- " If the lines are plotted representing in all cases the same percentage variation of illumination, the closeness of the lines to each other represents the 'illumination gradient', or the rate at which the illumination is changing from place to place on the plane of reference, and consequently the lack of uniformity in the illumination."[2] The isolux curves of the three lighting systems for the 30" plane will be found on pages 20, 21 ,and 22. The percentage variation between the lines is 25%, and curves of 50%, 75%, and 100% have been plotted for

each. In Direct System "A" the lines are very close together, indicating a poor degree of uniformity. Directly beneath each fixture over 175% illumination is obtained, while there is only 20% at the wall, indicating a very steep illumination gradient. Thus, an excessive intensity prevails in the center of the room beneath each fixture and comparative darkness near the walls.

A glance at the isolux curves for Direct System "B" will show that the uniformity of illumination furnished by this system is far superior to that of system"A". Although the highest intensity is, as in system "A", obtained directly beneath the fixtures, its value does not exceed 120%. Over the entire area enclosed by a rectangle whose sides are 3' from the walls of the room, the illumination is extremely uniform, varying not more than ten or fifteen percent from normal at any point. Thus it is shown that from the standpoint of uniformity system "B" is much better than system "A", although the same wattage of lamps is used.

In the curves for the indirect system, page 22, the distance from line to line is large, indicating that the uniformity is good, although not so good as that of Direct System "B". About one-third of the room receives 100% illumination, 50% being obtained near the walls. However, most of the room gets an illumination of 75% or more, but this is not objectionably low because with indirect light a lower intensity is required than with direct light. This is due to the fact that with the former there are no exposed light

sources or brilliant spots which would cause the pupil of the eye to contract and thus necessitate a higher intensity.

The isolux curves of each of three systems for the 3' plane do not differ materially from those for the 30" plane, except that the average intensity is somewhat higher, as would of course be expected, causing the curves to be shifted out farther from the center of the room.

The 5' plane isolux curves for the two direct systems show a much higher average intensity than that of the lower planes. The illumination gradient of system "A" is very steep, over 375% of normal intensity being obtained directly under each fixture, and but 20% at the blackboard. System "B" also has a rather steep gradient in this plane, although nothing like that of system "A", blackboard illumination being 30%. The curves of the indirect system for this plane are radically different from those of either of the direct systems save in one respect --the gradient is steeper than for the lower planes. The average intensity is somewhat lower than for the 30" or 3' planes, 100% being obtained only in a small zone directly beneath the units. Blackboard illumination is no better than with Direct System "A" .

From the foregoing it is seen that the most uniform illumination is given by the Direct System "B" in the 30" and 3' planes, the indirect system being second and Direct System "A" a poor third. The latter is not very uniform, small zones beneath the fixtures

being excessively bright and points a few feet distant insufficiently lighted. This feature alone would be sufficient reason for rejecting this system, but in addition to this serious fault it has several others. The group of four lamps on each fixture constitute a light source of high intrinsic brilliancy, notwithstanding the fact that the lamps are bowl-frosted, and, on account of the extreme length of the room, persons in the rear of the room would get the brilliant light directly in their eyes. Another fault is that on account of the central position of the fixtures, shadows would be cast, and many persons taking notes or reading would be in their own light.

Direct System "B", while furnishing a very uniform illumination, is open to one of the serious objections to system "A", i.e., that exposed light sources are directly in the line of vision of those occupying seats in the back part of the room. For an ordinary-sized class room with a fairly high ceiling this system would be quite satisfactory, since no one would then get the light in his eyes. The trouble caused by shadows would not be experienced to any extent with this system.

With the indirect system there are no brilliant light sources in the line of vision of any person in the room. There is a very noticeable absence of either excessively illuminated spots or dark spots, and the whole room is filled with light. No shadows are cast because of the diffuse reflection, which takes place at all angles

from the ceiling and walls. The average intensity does not vary considerably in different planes, which indicates almost perfect diffusion. Thus it is shown that although the uniformity of illumination is not quite so good as with Direct System "B", the indirect system has many other advantages not to be had with the direct system, and none of its defects. The indirect system would be the more expensive to operate, however. In the case of the small lecture room the wattage of either of the two direct systems is 720, while that of the indirect system is 1200, or 1 2/3 as great.

Having completed the comparison of the three methods of illumination, the conclusion is that the indirect system is far superior to either of the direct systems; that of the two direct systems, system "B" is the better; and that for lighting rooms as long and narrow as the lecture room taken for the purpose of illustration, it is almost imperative that indirect methods be used.

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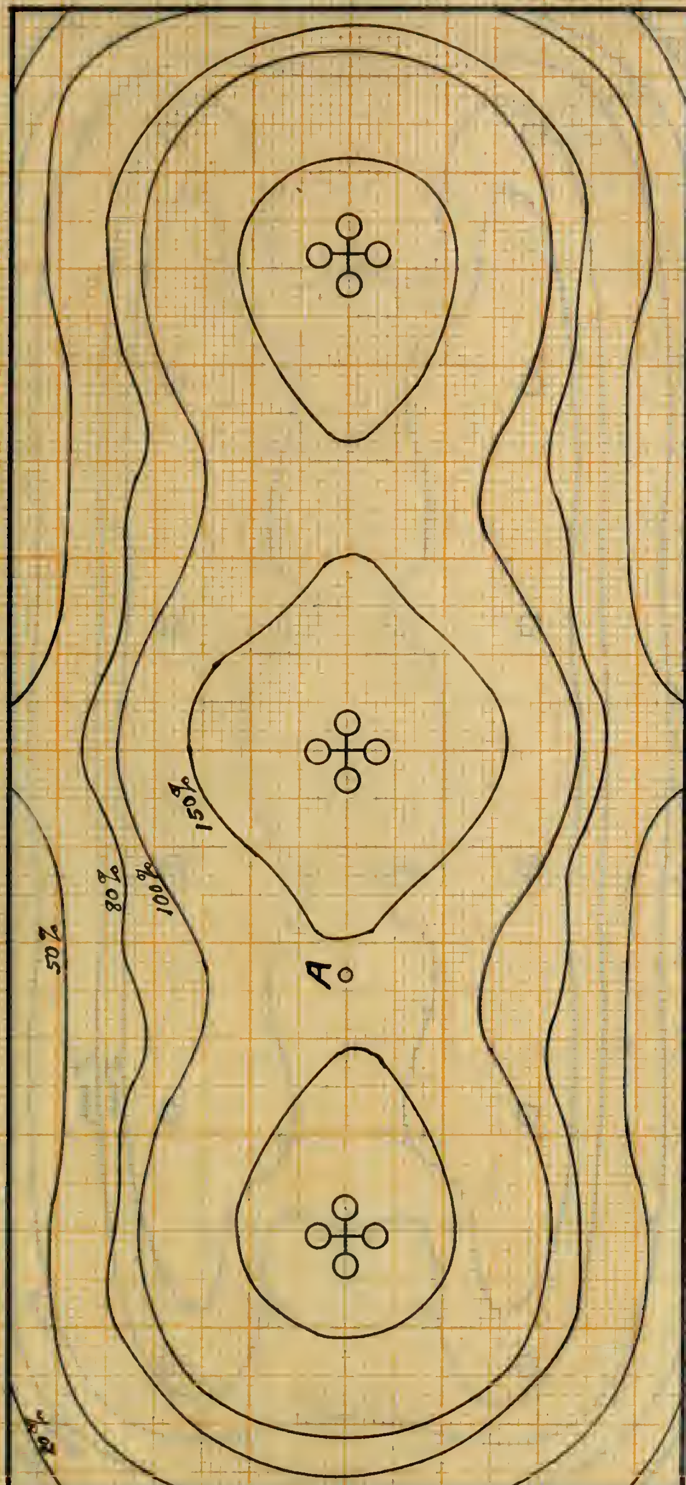
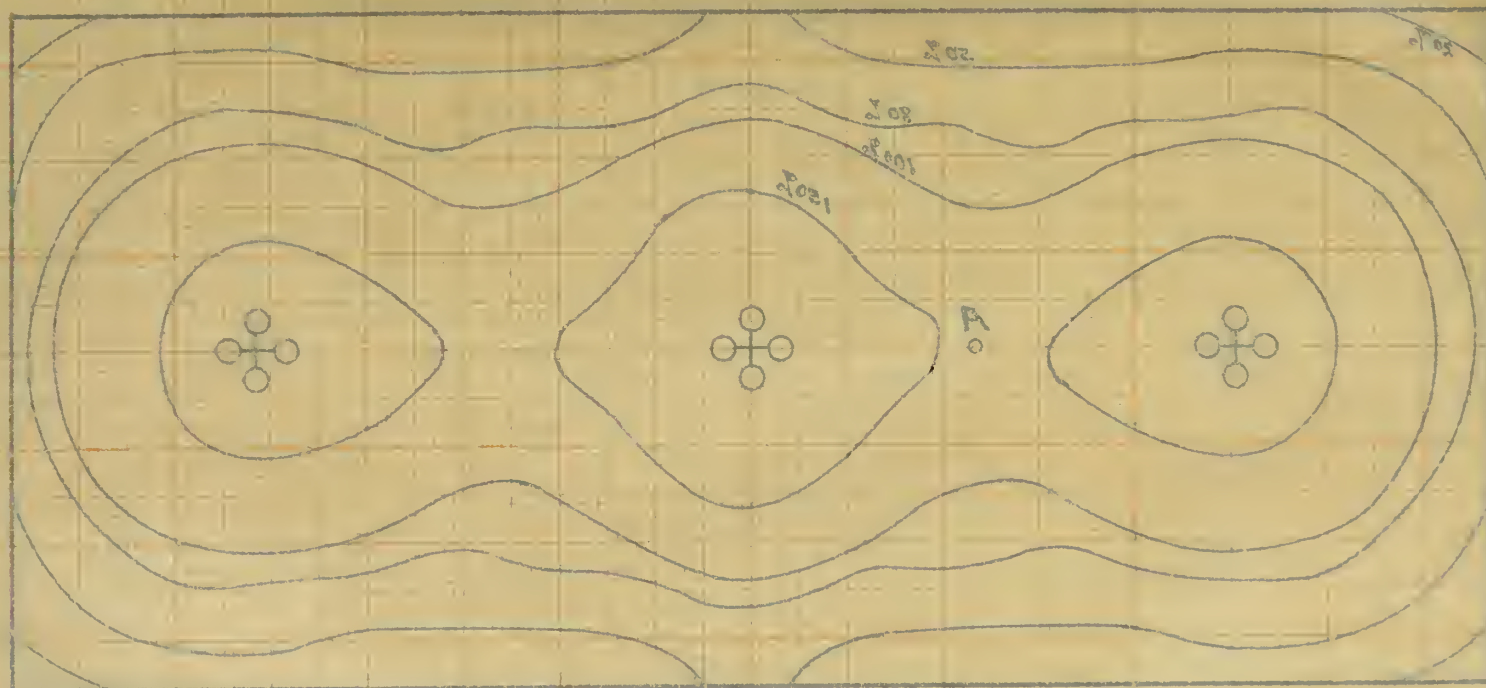
ISOLUX CURVES



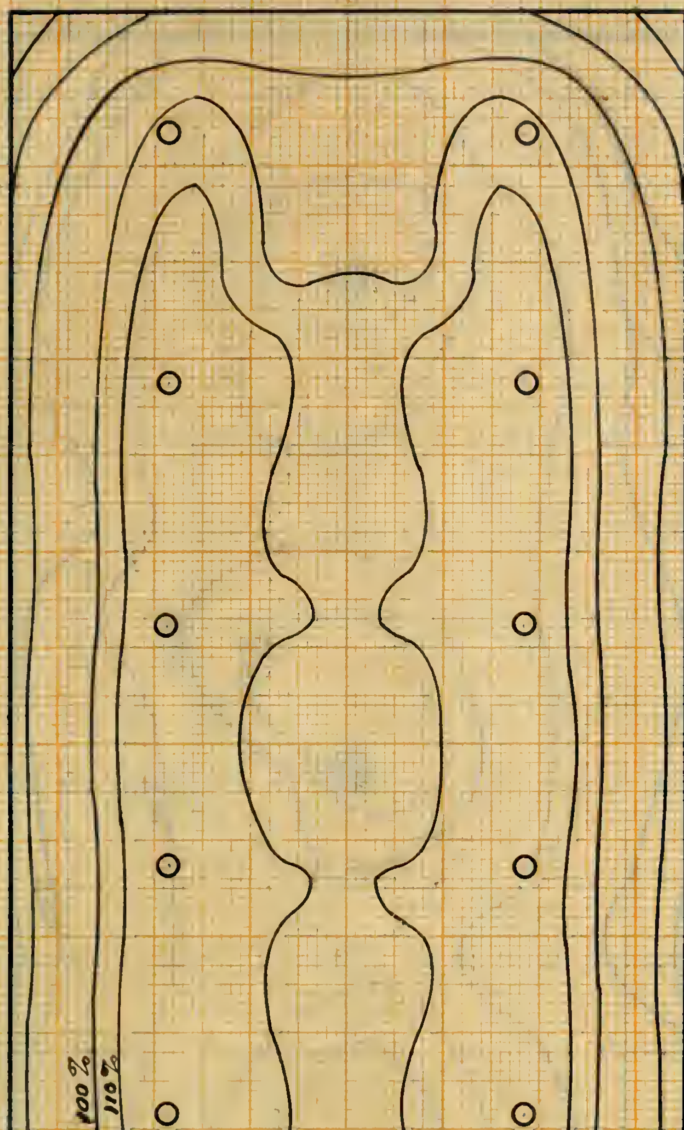
DIRECT SYSTEM "A".
2.5 ft. candles = 100%.
$2\frac{1}{2}'$ plane.

ISOLUX CURVES



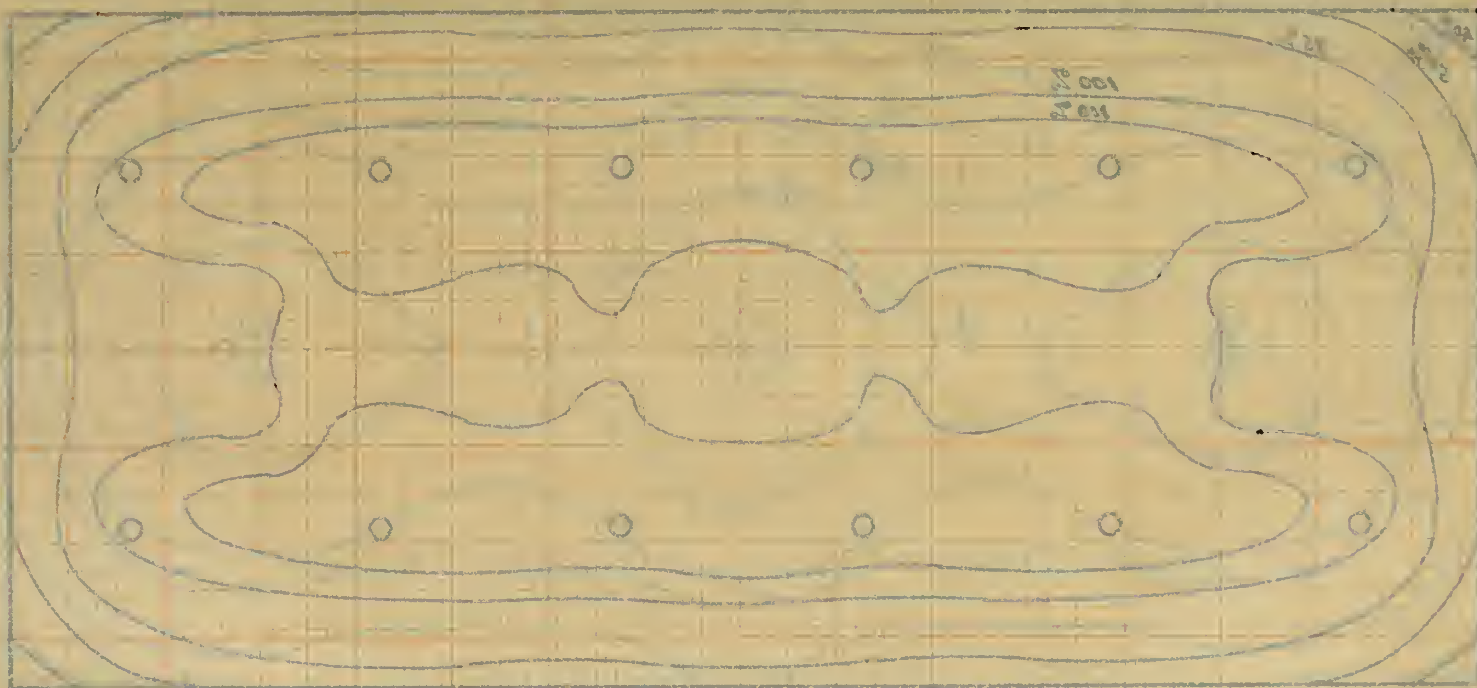
DIRECT SYSTEM "A".
2.5 ft. candles = 100%.
2½' plane

ISOLUX CURVES



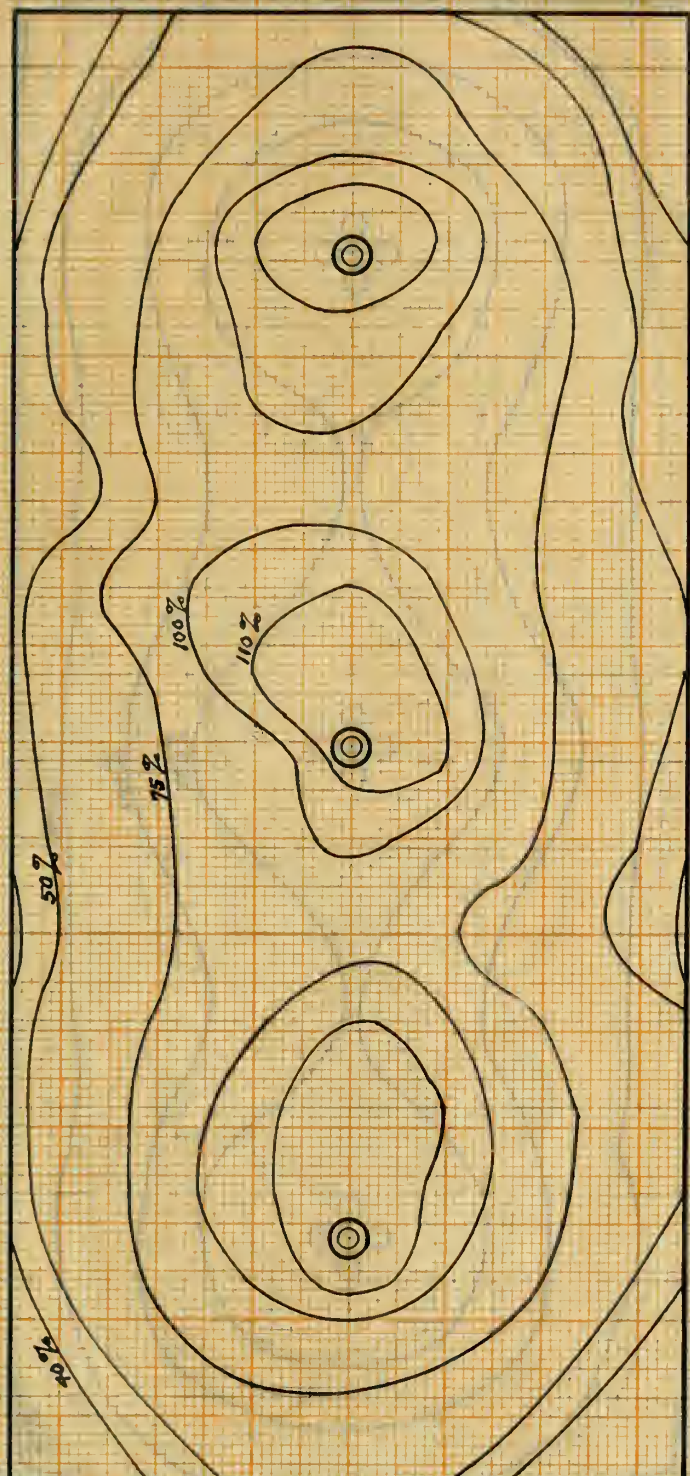
DIRECT SYSTEM "B"
2.5 ft. candles = 100%.
$2\frac{1}{2}$' plane.

ISOLUX CURVES



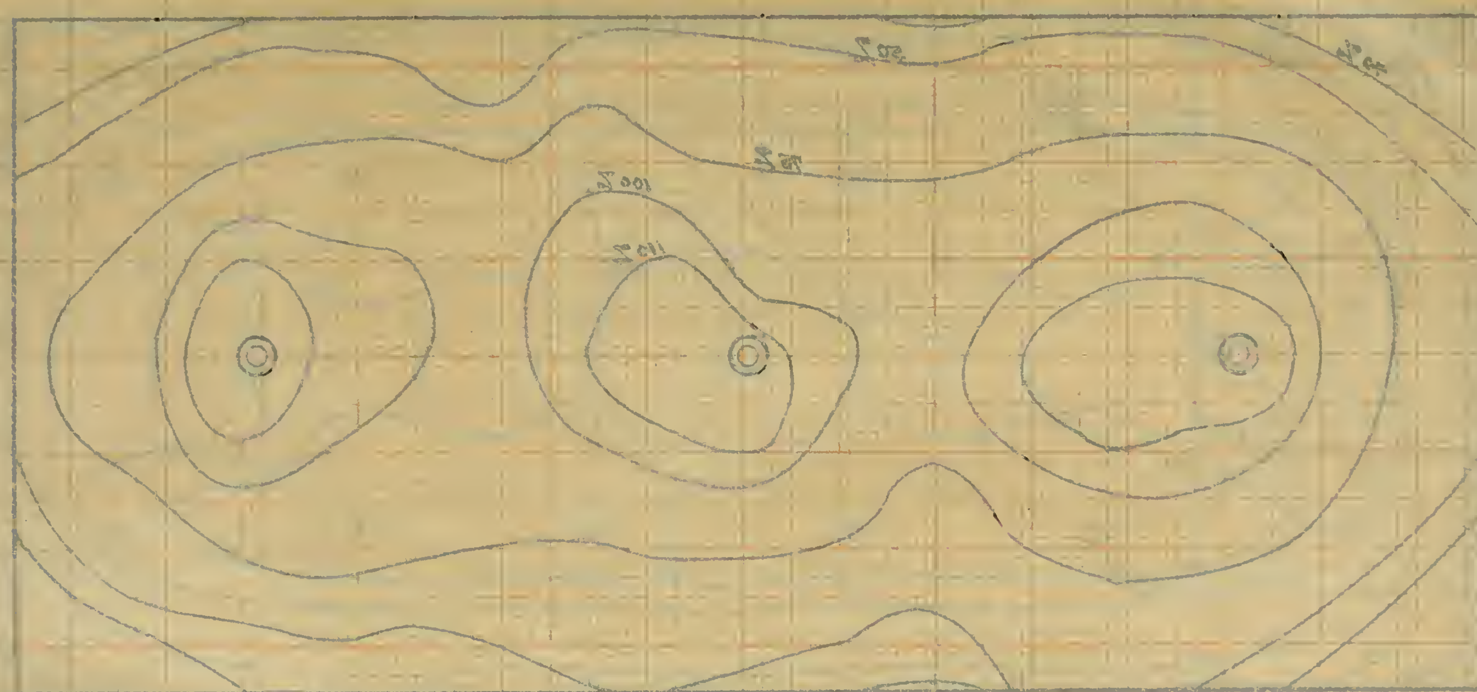
Direct System B

ISOLUX CURVES



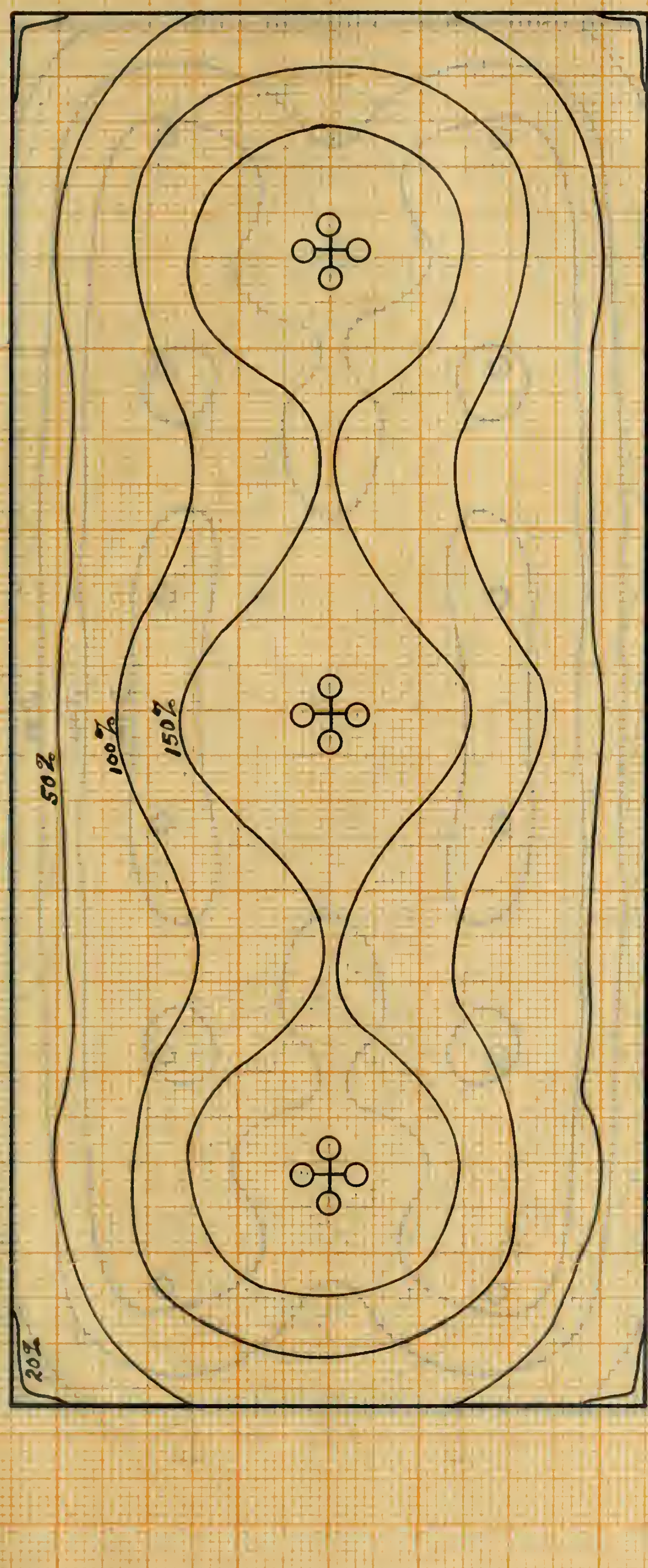
INDIRECT SYSTEM
2.5 ft. candles = 100%
2½' plane

ISOLUX CURVES



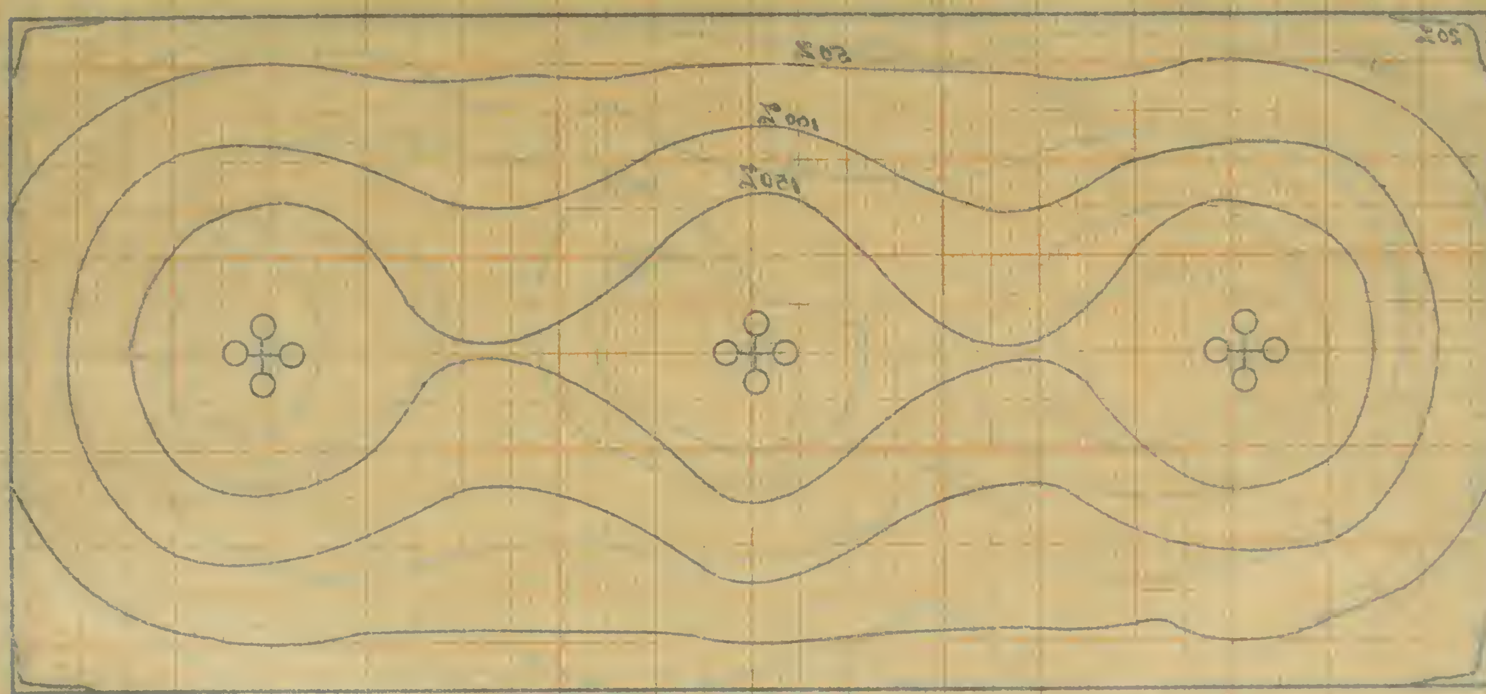
INDIRECT SYSTEM
2.5 ft. candles = 100%
$2\frac{1}{2}$' plane

ISOLUX CURVES



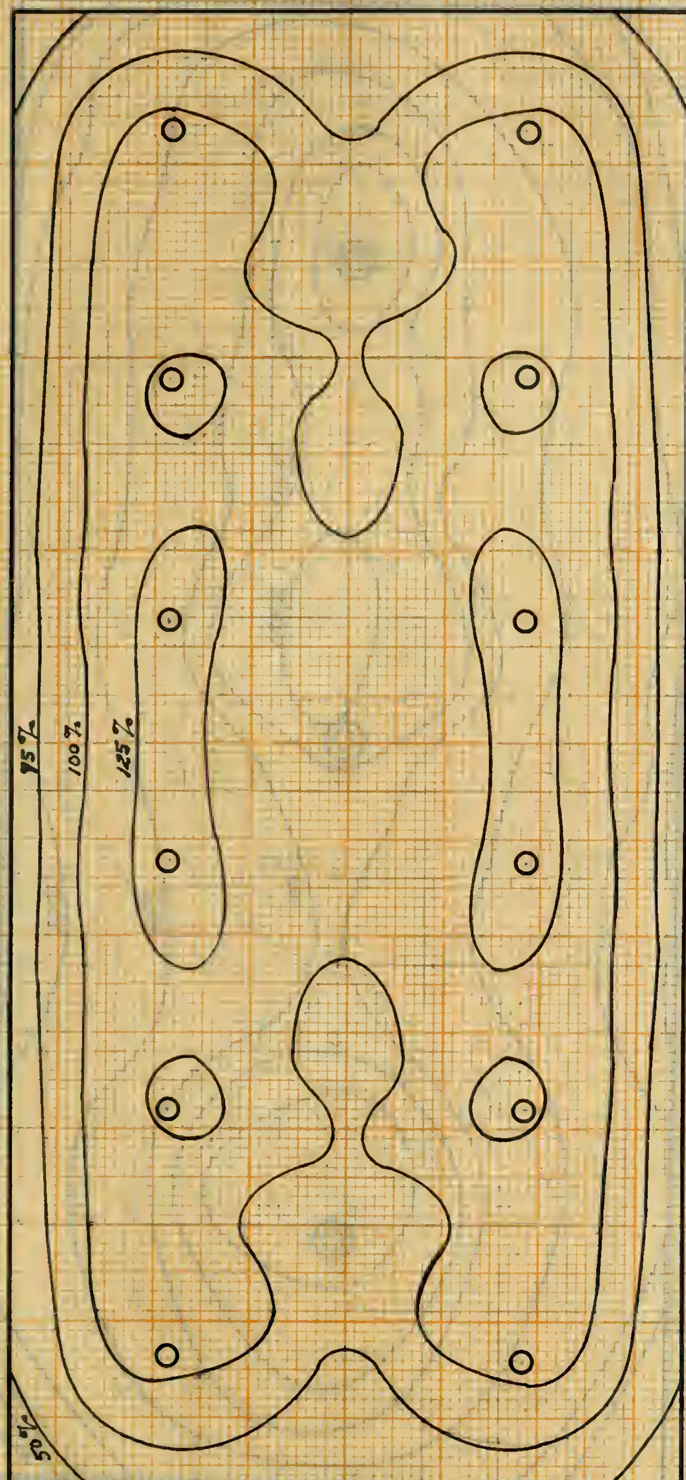
DIRECT SYSTEM "A".
2.5 ft. candles = 100%.
3' plane.

ISOLUX CURVES



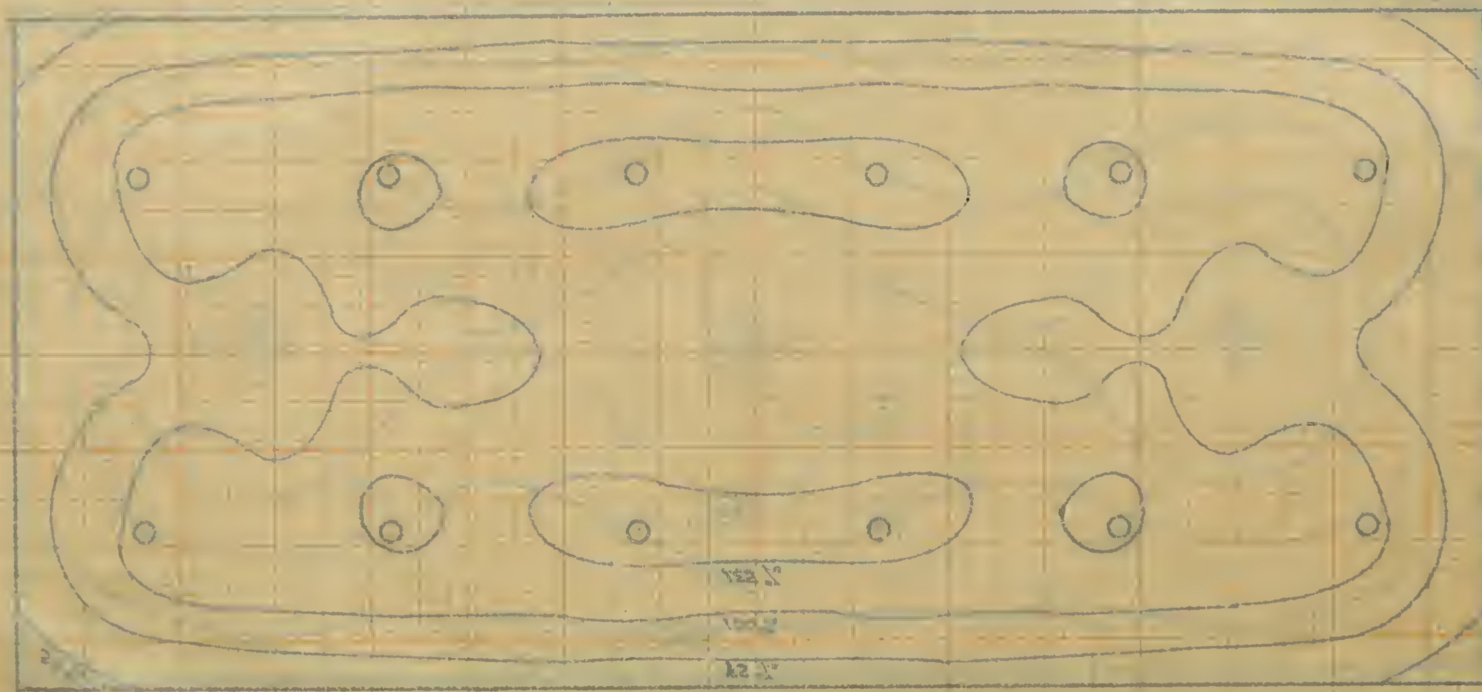
DIRECT SYSTEM "A"
2.5 ft. candles = 100%
3' plane

ISOLUX CURVES



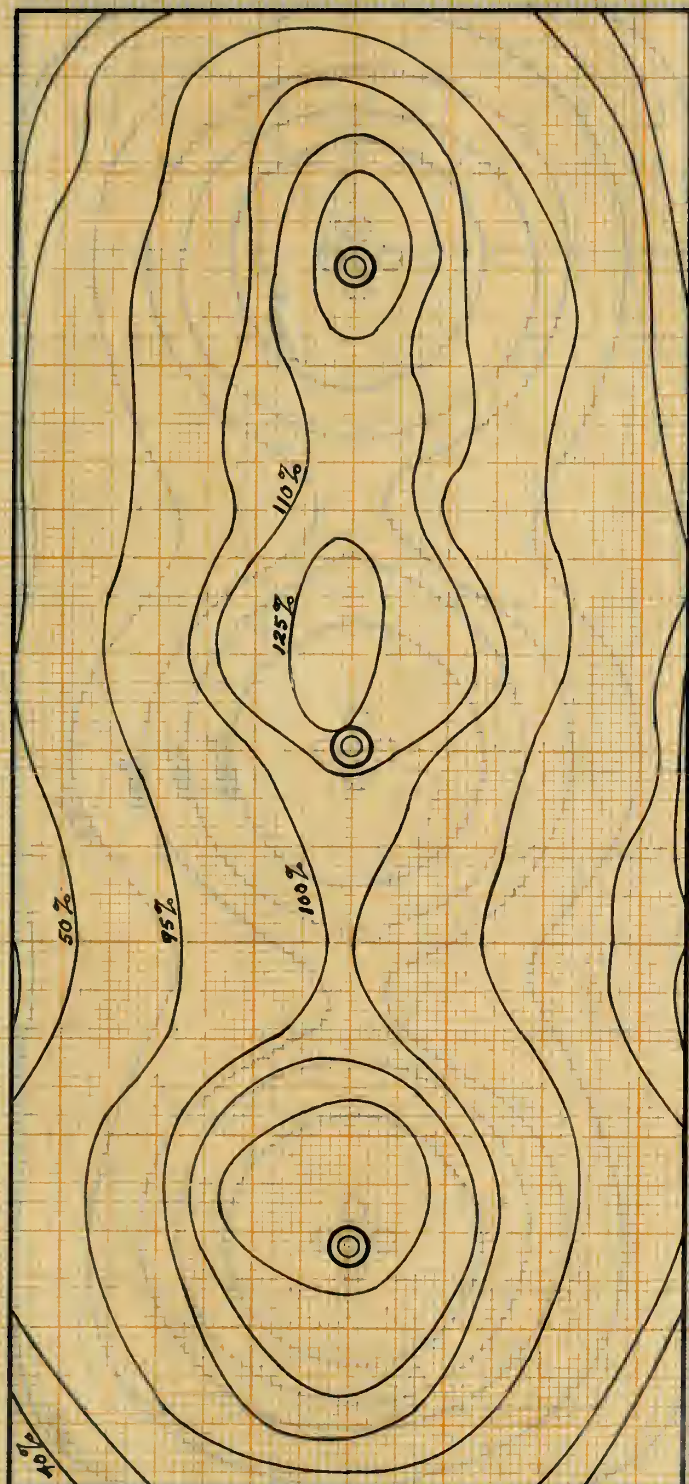
DIRECT SYSTEM "B".
25 ft. candles = 100%.
3' plane

Direct System B.



ISOLUX CURVES

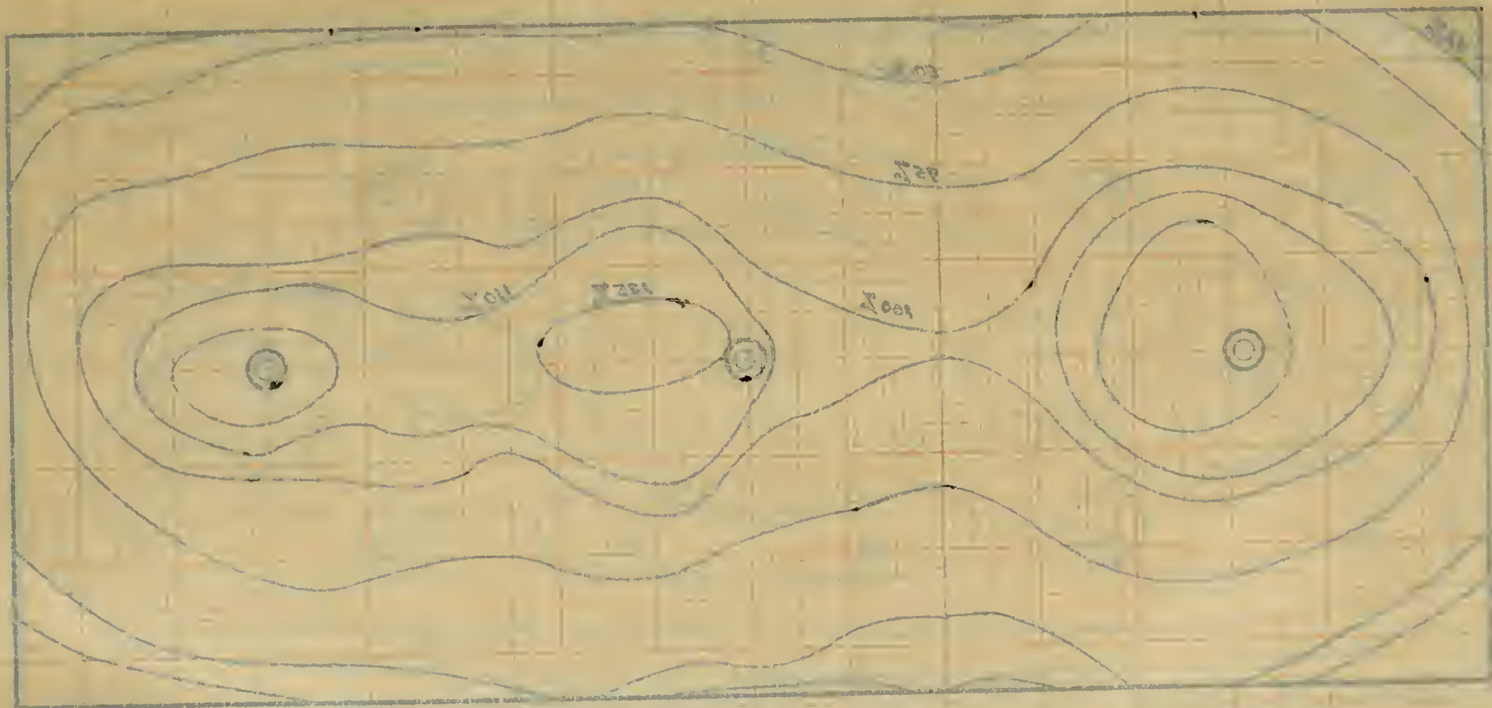
ISOLUX CURVES



INDIRECT SYSTEM
2.5 ft. candles = 100%
3' plane

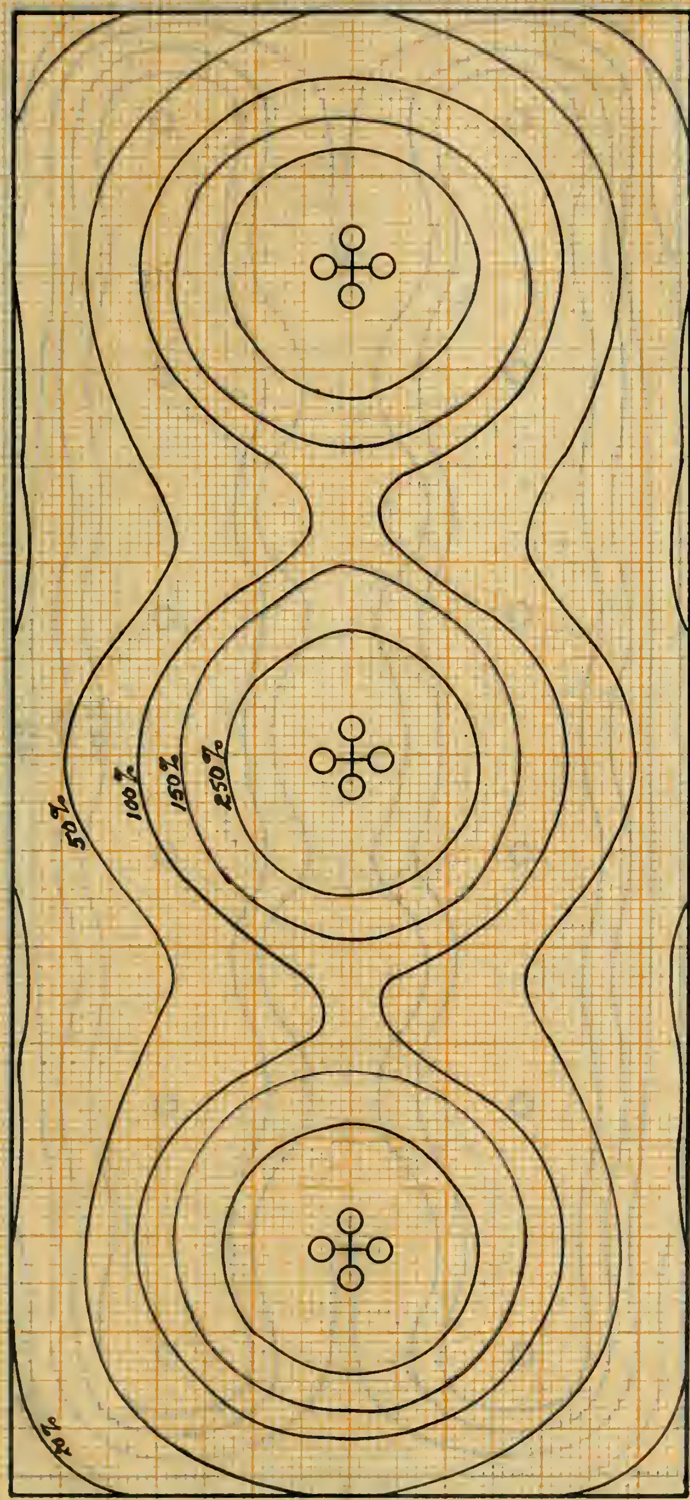
25.

ISOLUX CURVES



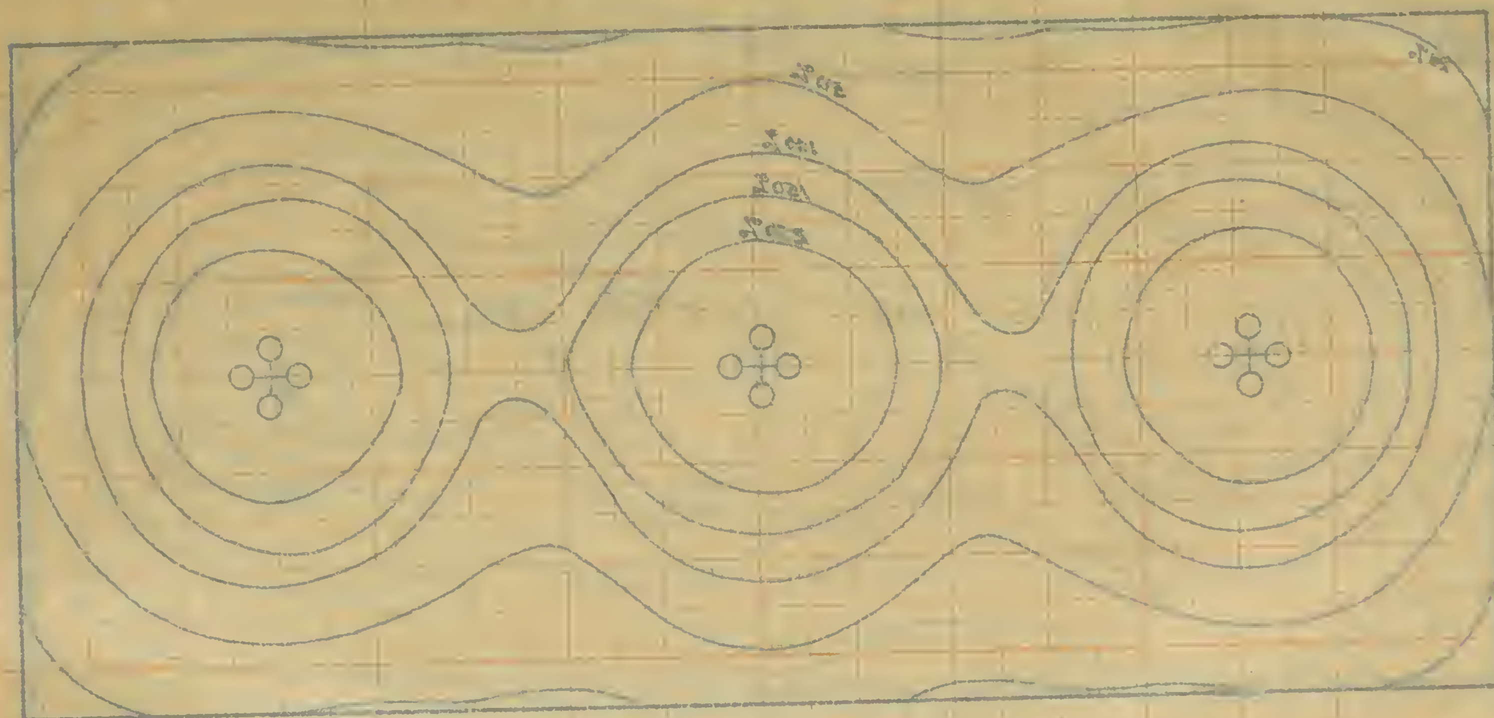
INDIRECT SYSTEM
2.5 ft candles = 100%
3' plane

ISOLUX CURVES



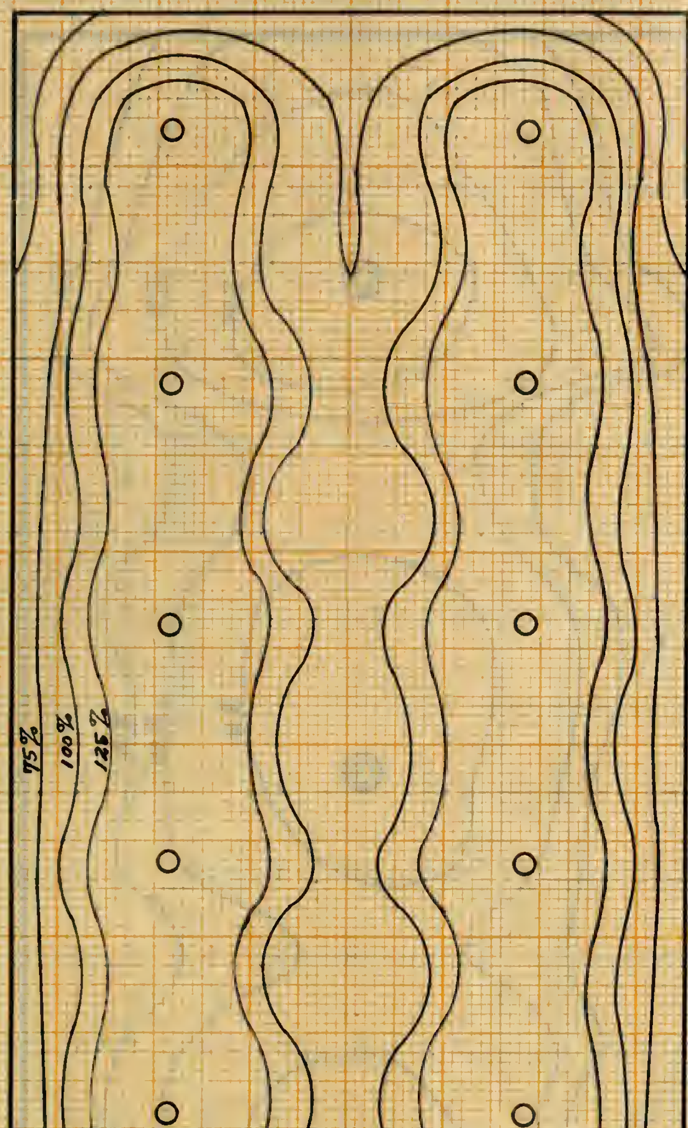
DIRECT SYSTEM "A."
2.5 ft. candles = 100%.
5' plane.

ISOLUX CURVES



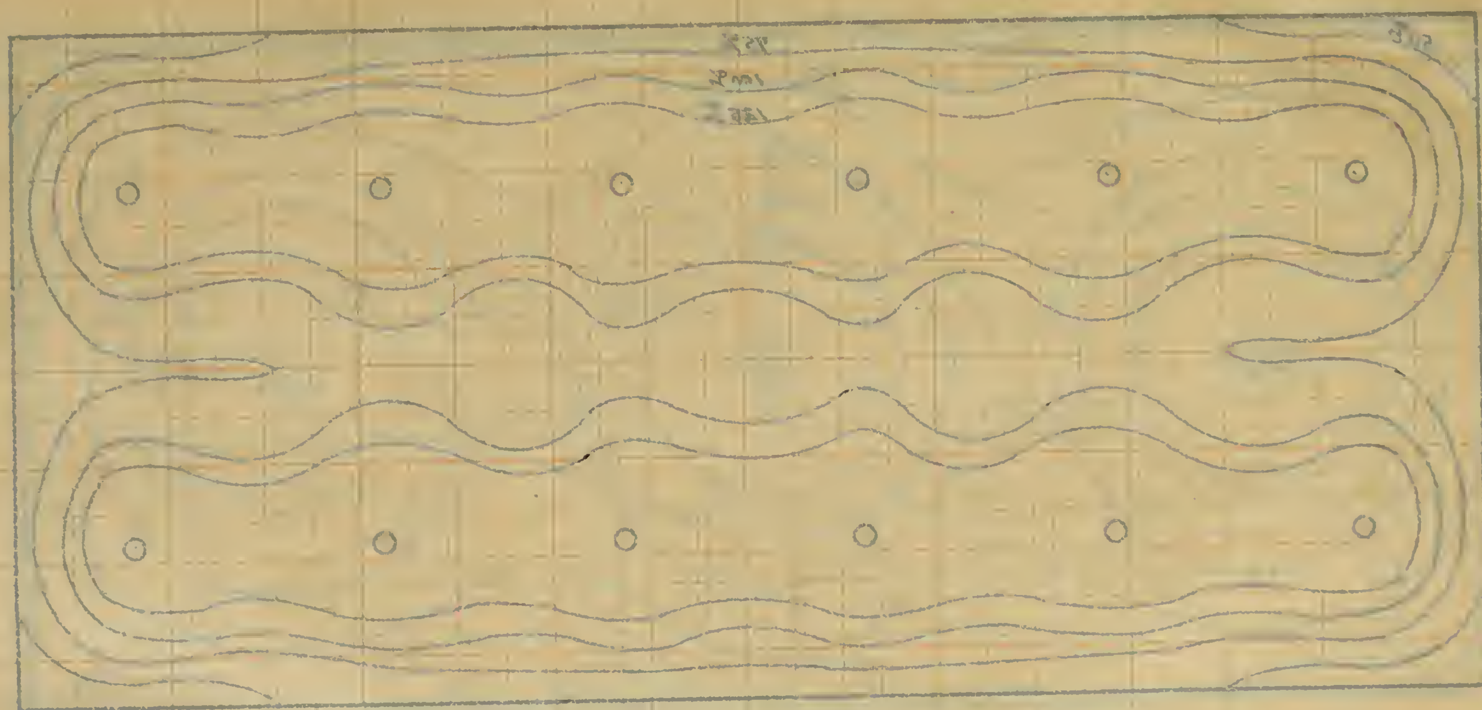
DIRECT SYSTEM "A".
2.5 ft candles = 100%.
5' plane.

ISOLUX CURVES



DIRECT SYSTEM "B"
2.5 ft. candles = 100%.
5' plane.

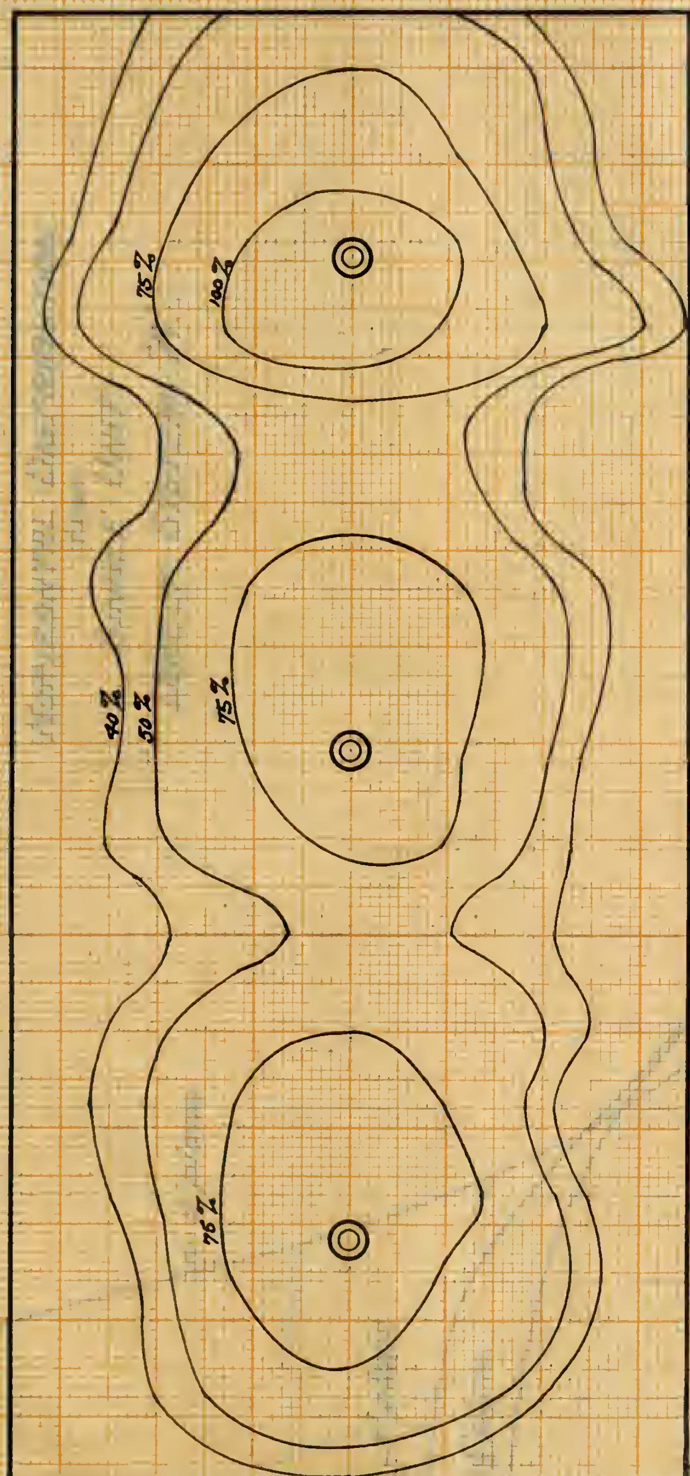
ISOLUX CURVES



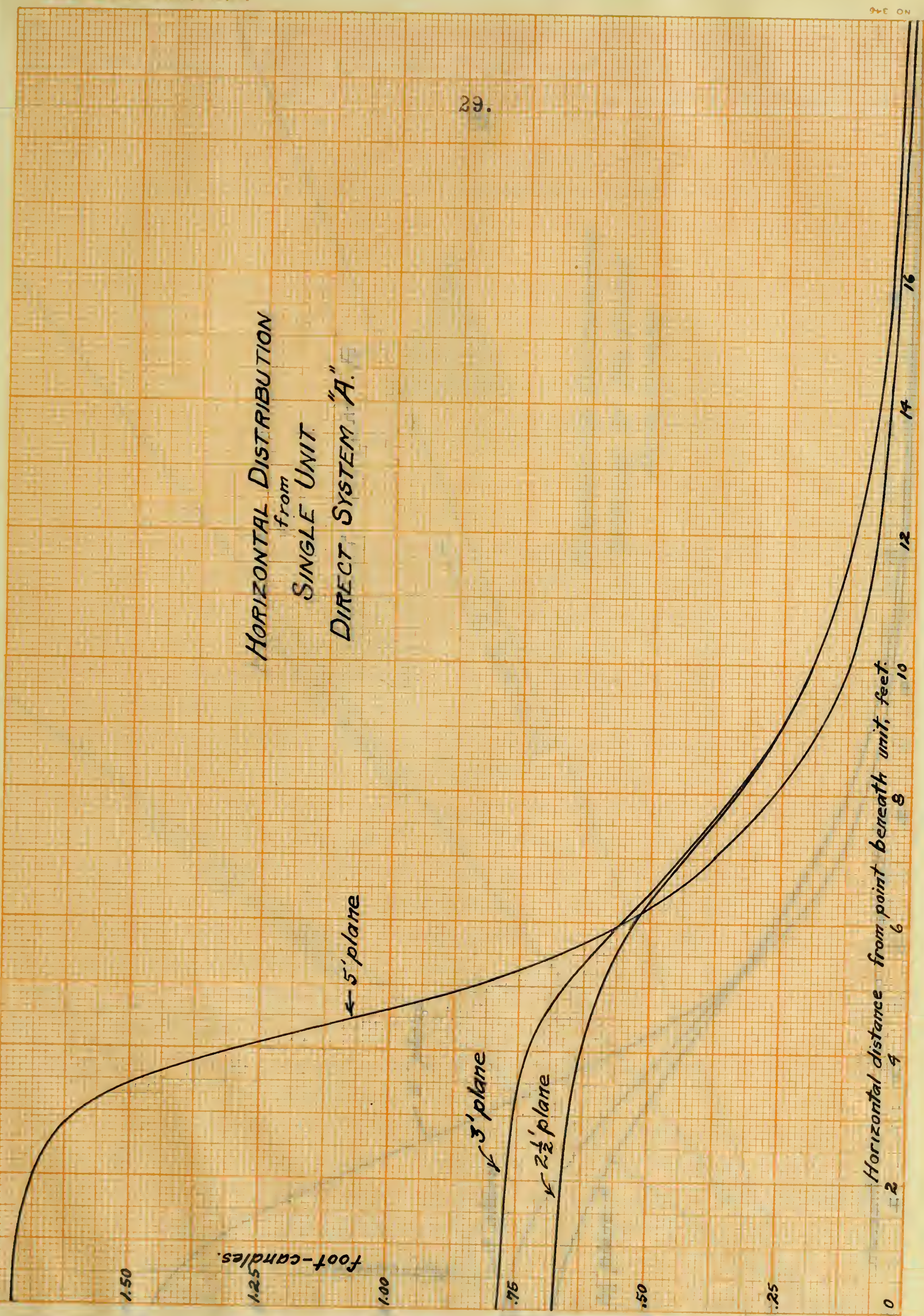
DIRECT SYSTEM "B"

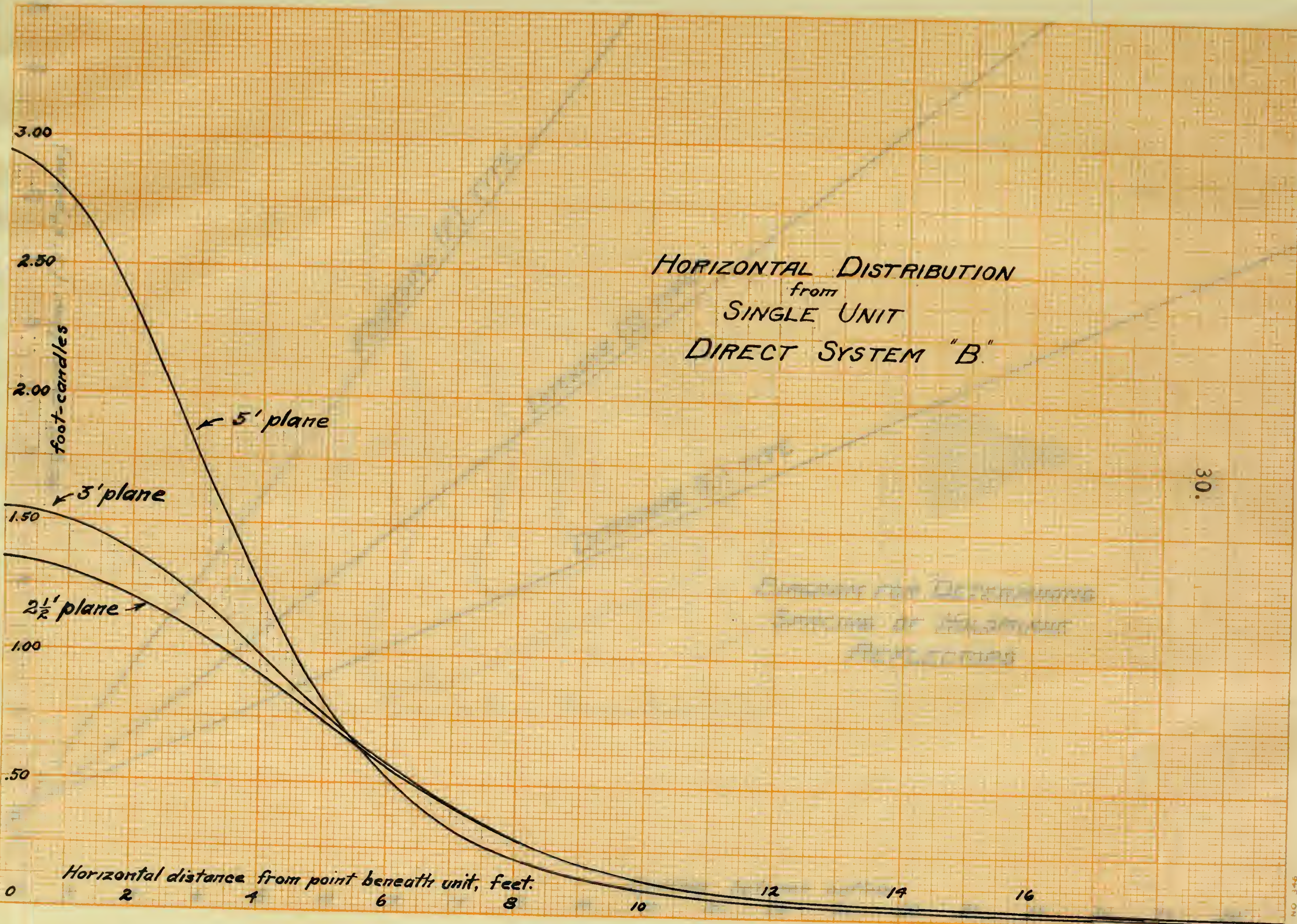
3' plane.

ISOLUX CURVES

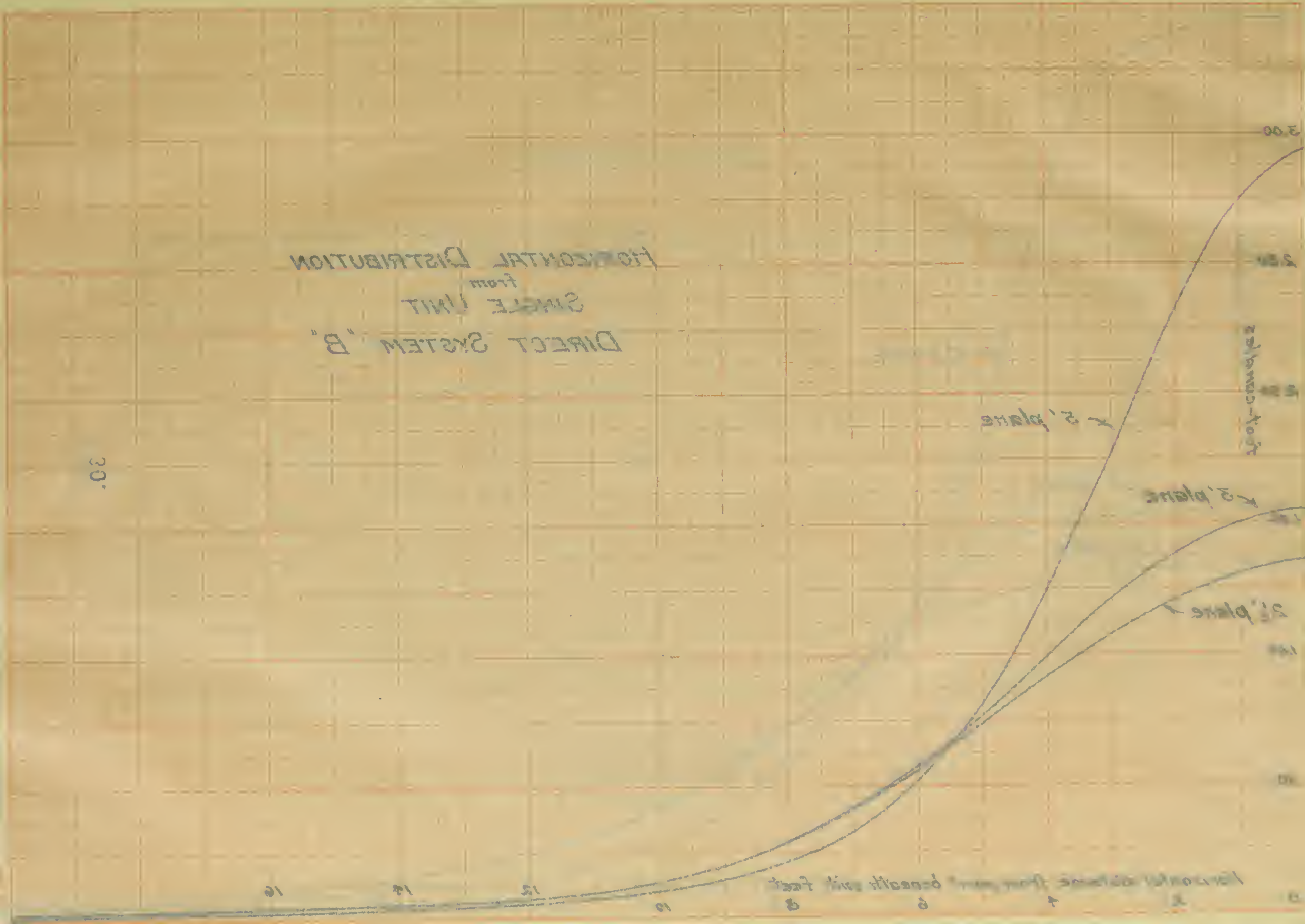


INDIRECT SYSTEM
2.5 ft. candles = 100%.
5' plane


HORIZONTAL DISTRIBUTION
from
SINGLE UNIT
DIRECT SYSTEM "A."
5' plane
3' plane
2½' plane
foot-candles.
1.50
1.25
1.00
.75
.50
.25
0
2
4
6
8
10
12
14
16
Horizontal distance from point beneath unit, feet.


HORIZONTAL DISTRIBUTION
from
SINGLE UNIT
DIRECT SYSTEM "B"
foot-candles
3.00
2.50
2.00
1.50
1.00
.50
5' plane
3' plane
2½' plane
Horizontal distance from point beneath unit, feet.
0
2
4
6
8
10
12
14
16

30.



HORIZONTAL DISTRIBUTION
from
SINGLE UNIT
DIRECT SYSTEM "B"
5' plane
3' plane
2½' plane
foot-candles
3.00
2.50
2.00
1.50
1.00
.50
0
2
4
6
8
10
12
14
16
Horizontal distance from point beneath unit feet

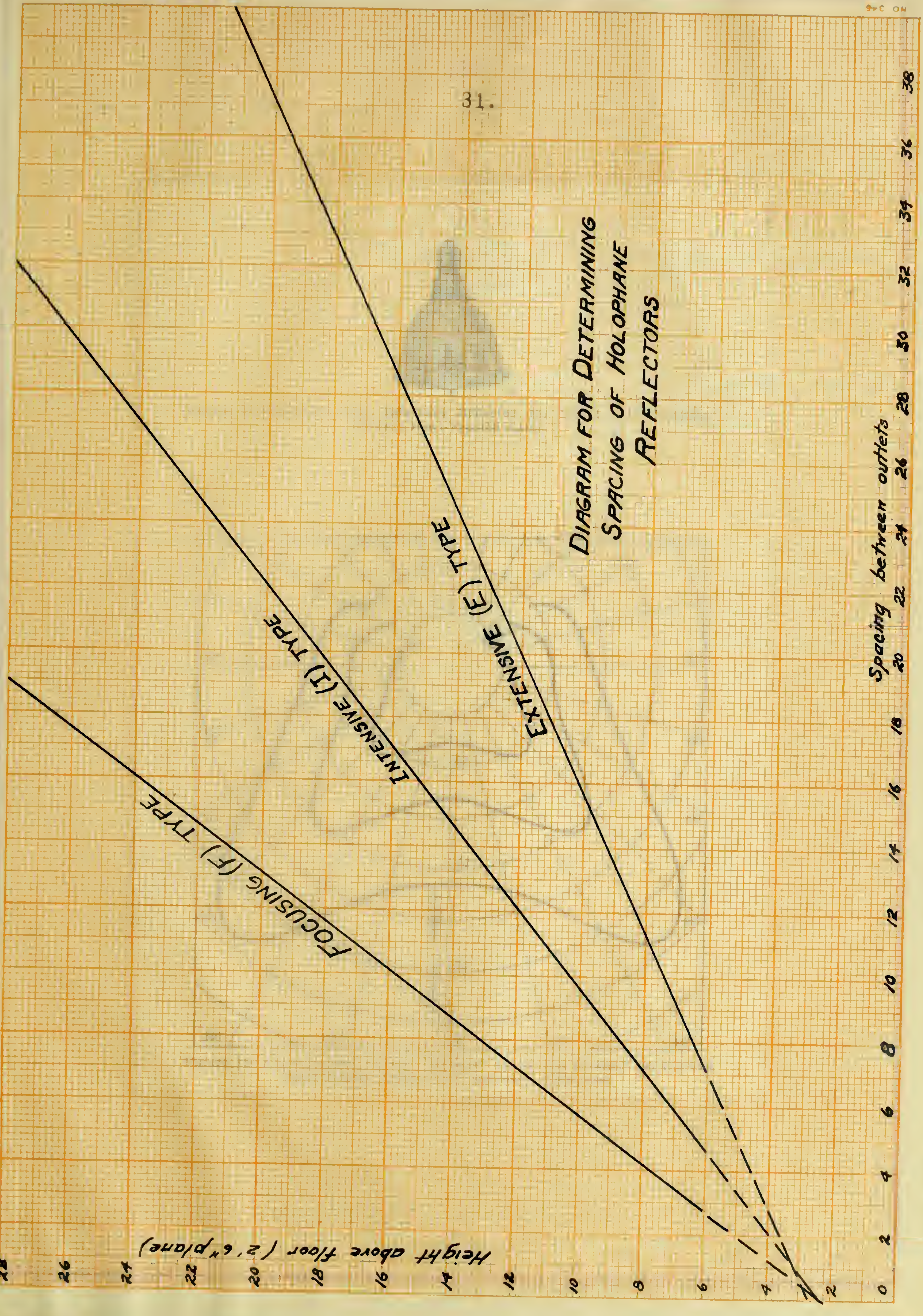


DIAGRAM FOR DETERMINING
SPACING OF HOLOPHANE
REFLECTORS
EXTENSIVE (E) TYPE
INTENSIVE (I) TYPE
FOCUSING (F) TYPE
Spacing between outlets
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
Height above floor (2' 6" plane)
2 4 6 8 10 12 14 16 18 20 22 24 26 28

31.

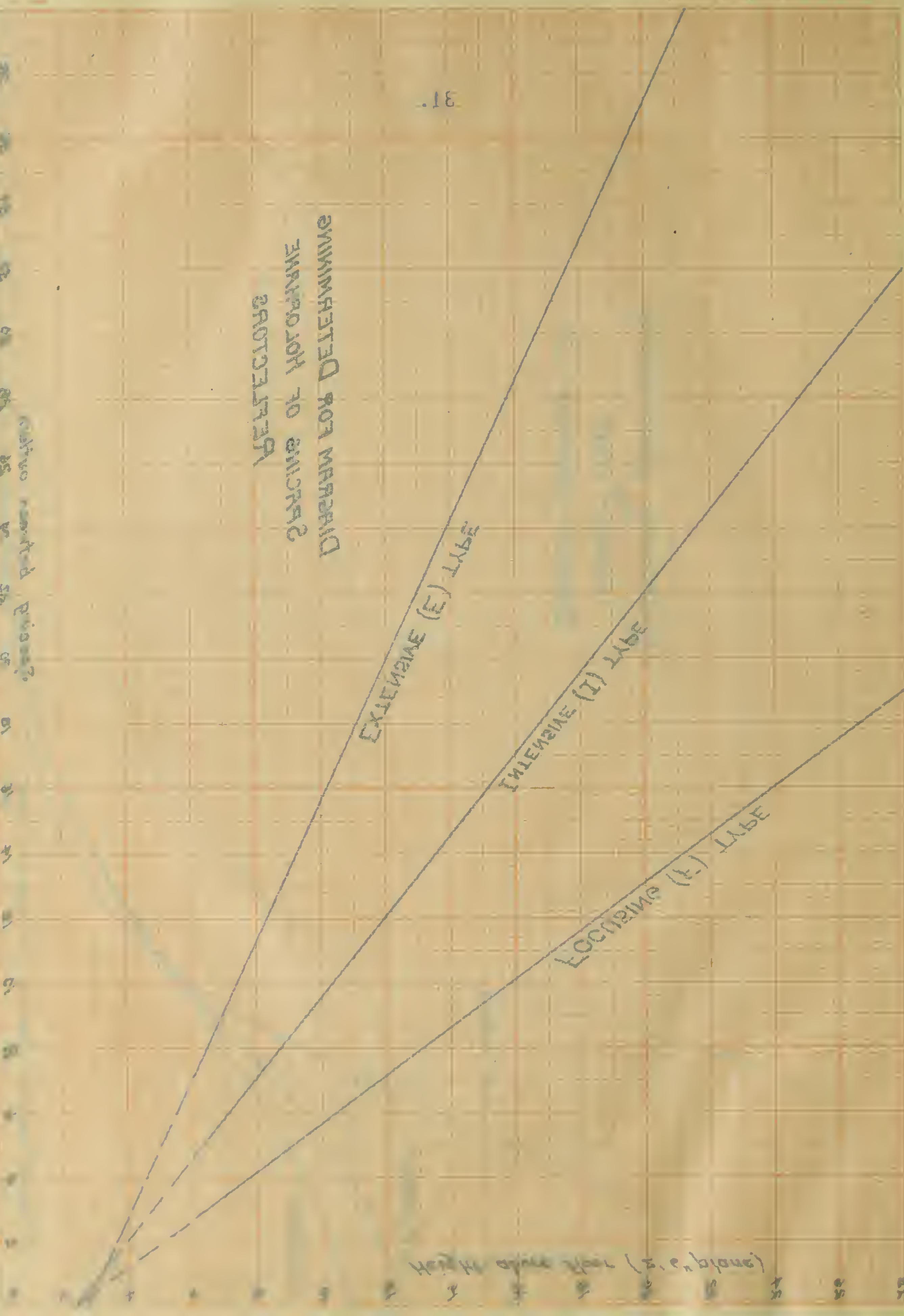


DIAGRAM FOR DETERMINING
SPACING OF HOLOPHANE
REFLECTORS
EXTENSIVE (E) TYPE
INTENSIVE (I) TYPE
FOCUSING (F) TYPE
Spacing between outlets
Height above floor (i.e. "plane)

Figure 10—Extensive High Efficiency Reflector No. 106250 with "MAZDA" 60-watt Bowl-Frosted Lamp.

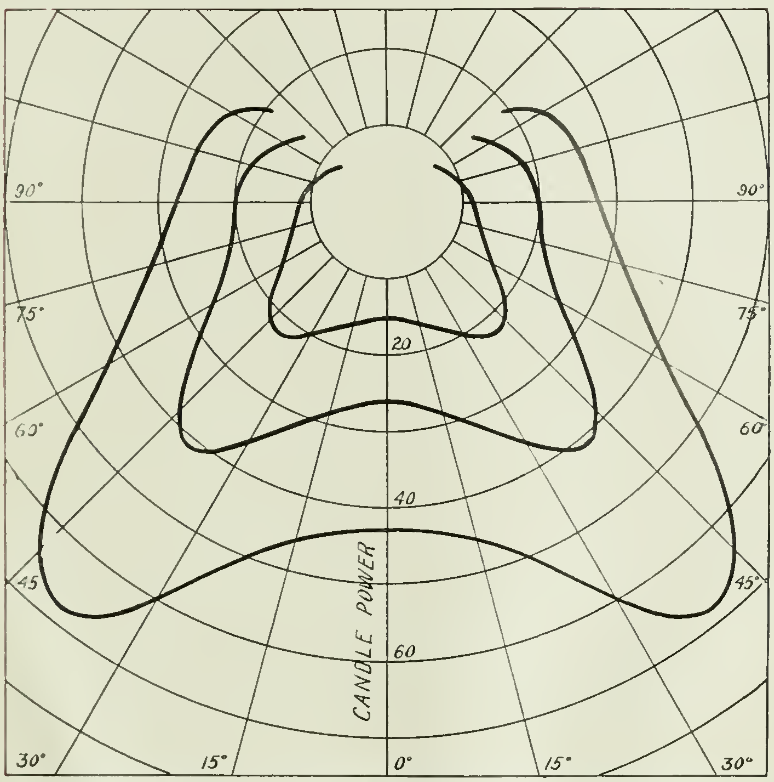


Figure 11—Characteristic Curves "MAZDA" 25, 40 and 60-watt, 100-125-volt Bowl-Frosted Lamps with Extensive Reflectors.

Figure 14—Intensive High Efficiency Reflector No. 106150, with "MAZDA" 60-watt Bowl-Frosted Lamp.

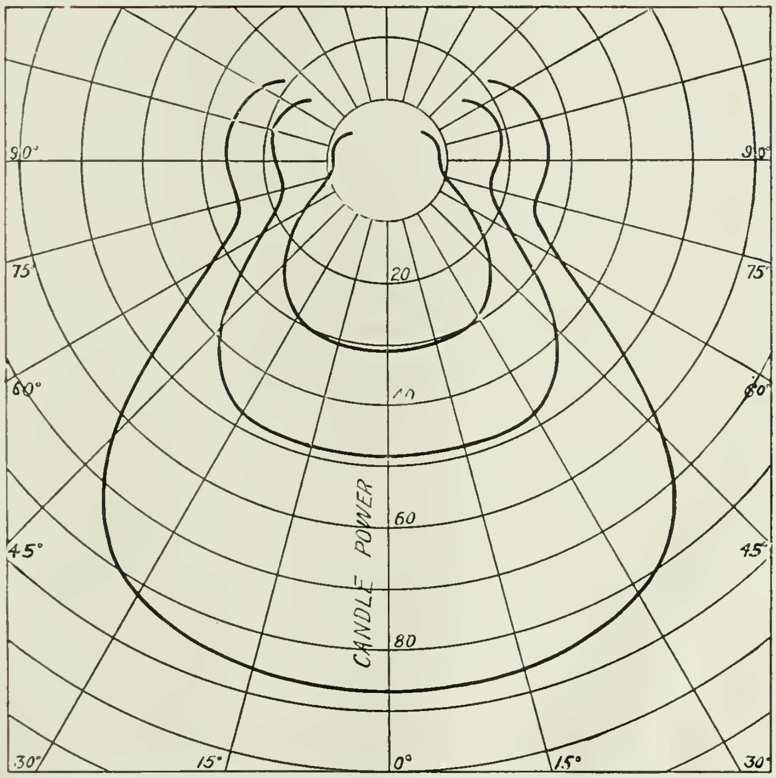


Figure 15—Characteristic Curves "MAZDA" 25, 40 and 60-watt, 100-125-volt Bowl-Frosted Lamps with Intensive Reflectors.

Figure 18—Focusing High Efficiency Reflector No. 106350, with "MAZDA" 60-watt Bowl-Frosted Lamp.

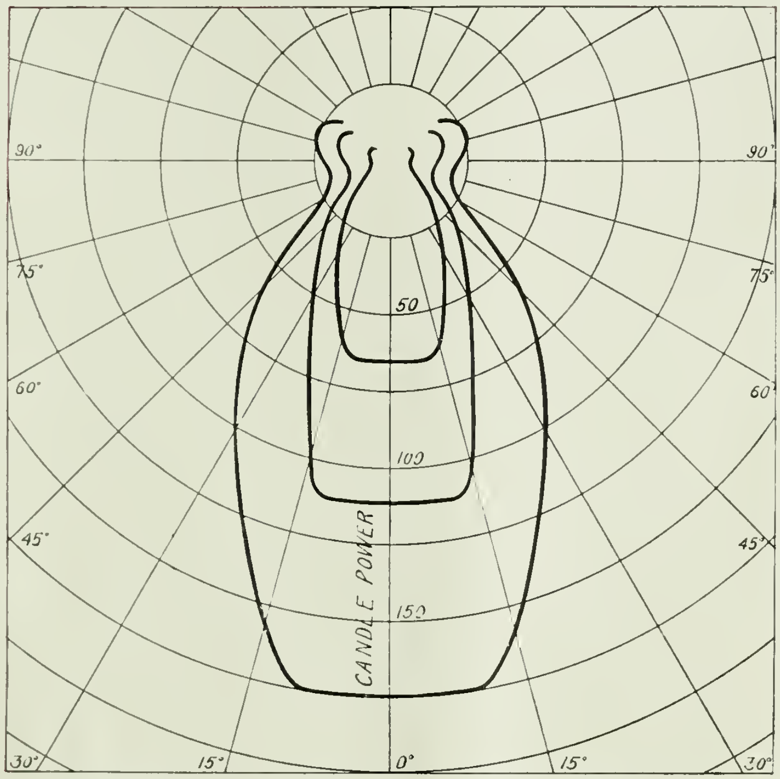


Figure 19—Characteristic Curves "MAZDA" 25, 40 and 60-watt, 100-125-volt Bowl-Frosted Lamps with Focusing Reflectors.

Fig. 4.

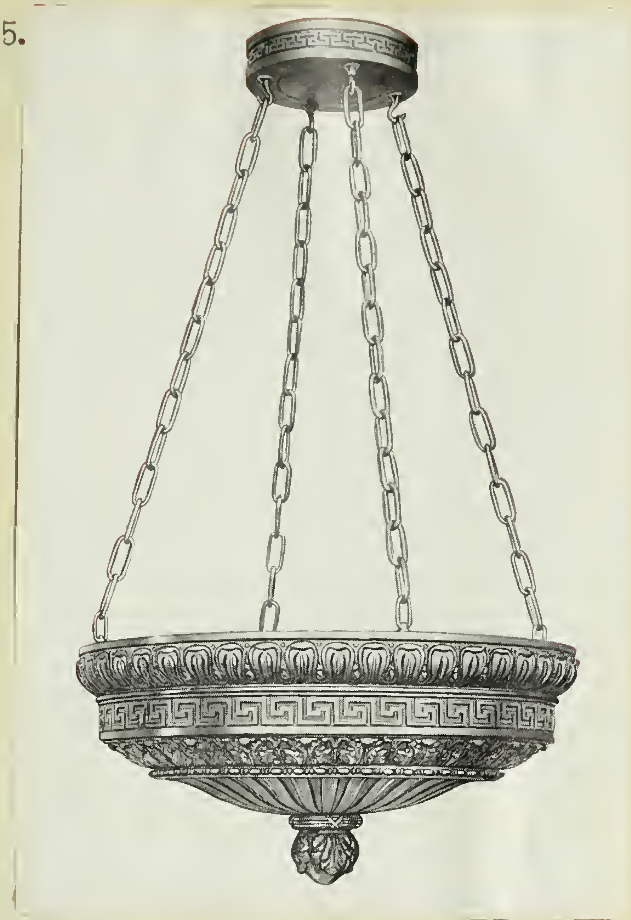
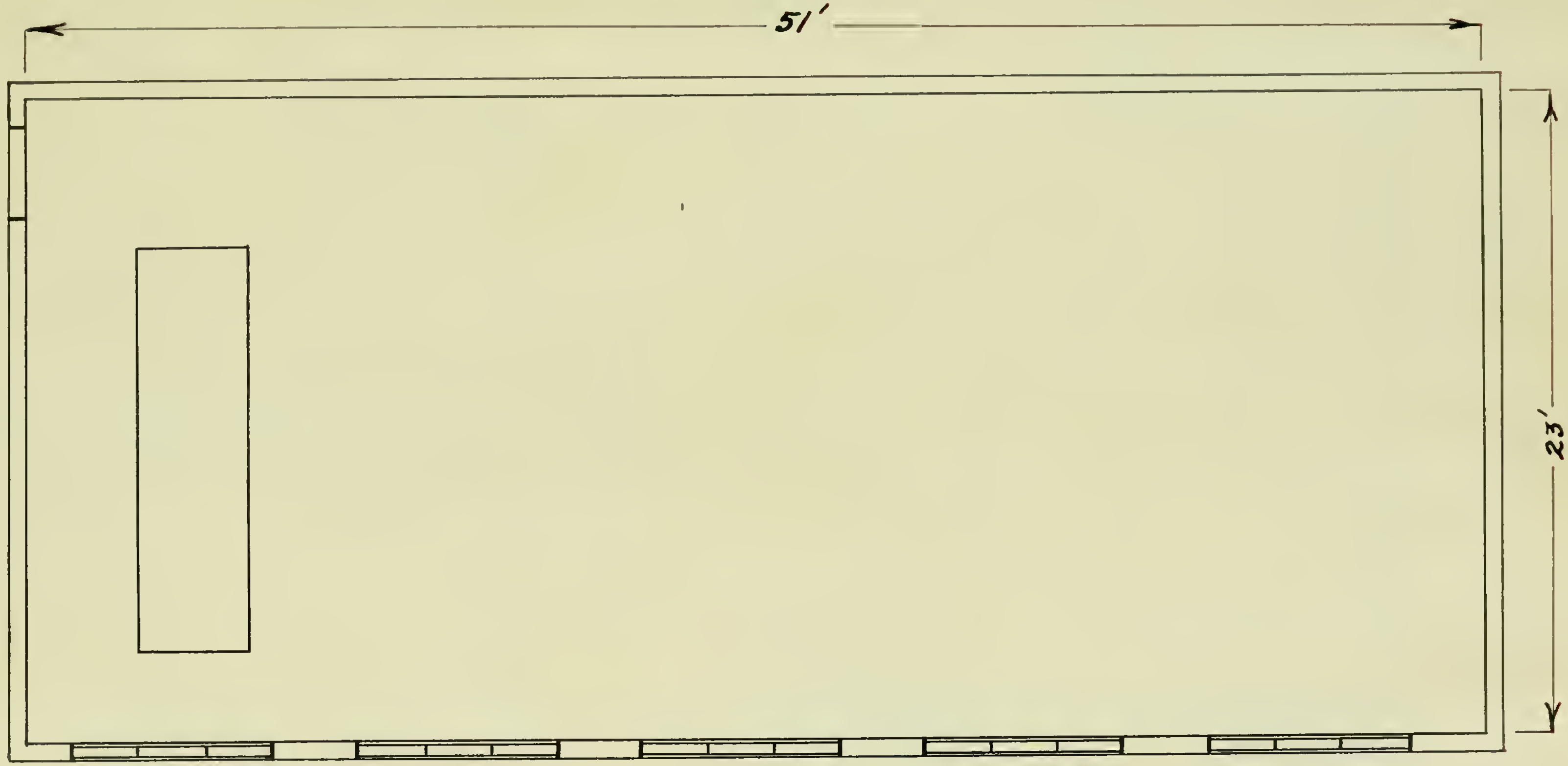


Fig. 5.

Fig. 6.



PLAN OF LECTURE ROOM

A P P E N D I X.

TABLE 1.

Required Intensity of Illumination.

Auditoriums, theaters	1-3 Ft.-candles.
Depots, Assembly halls, churches.	0.75-1.5 "
Drafting rooms.	5-10 "
Desk lighting	2- 5 "
Hotel rooms	2- 3 "
Offices	2- 3 "
Post-offices.	2- 5 "
Reading	1- 3 "
Clothing stores	4- 7 "
School rooms.	2- 3 "

TABLE 2.

Lumens and Watts of Tungsten Lamps.

Watts per lamp	25	40	60	100	150	250
Effective Lumens, 1 lamp,	95	160	250	420	630	1090
Lumens per watt . . .	3.8	4.0	4.2	4.2	4.2	4.3

TABLE 3.

Percentages of Increase over Calculated Illumination.

Ceiling	Walls	Increase
Very dark	very dark	0 %
Medium.	very dark	15 %

Medium	Medium	40 %
Very light	Very dark.	30 %
Very light	Medium	55 %
Very light	Very light	80 %

REFERENCES.

[1] J.R.Cravath, Electrical World(Monthly Edition), May, 1911: - - " The Engineering of Indirect Illumination."

[2] Sharp and Millar: Paper read before The Edison Assn., N.Y.